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**HUMAN-CENTRED WORKPLACE:
RE-FINDING PHYSICAL DOCUMENT IN AN OFFICE WORKPLACE**

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF
REQUIREMENTS FOR THE DEGREE

of

Master of Science in Computer Science

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Abstract

Today's typical busy schedules make it difficult for people to keep track, organize and search the documents they keep in their own office workplace. The consequences of less organized offices are often that people lose more time in searching for paper documents. To avoid the consequences of losing documents, some archive their physical documents according to their use and others place documents in highly visible areas. These strategies offer some comfort when searching the document, but the practice demands people to be somewhat organized. Even digital support for finding physical documents typically requires some organisation and order has observed. In this thesis, we describe a project that created a system, which does not require people to be orderly and aims at freeing people from the time-consuming job of sorting or sequencing their documents. The system generates and prints passive tags (Quick Response Code) on documents and uses cameras in the office to track changes in the document locations. The thesis describes the design, implementation and initial evaluation of the system 'Human-centred workplace (HCW).'

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1 Introduction

Digital and physical documents are an integral part of our (work) life. The types of documents range from official to personal documents with different levels of importance. In our work environment, digital and paper document co-exists. Over the times different systems have been used to manage digital and paper documents. In this chapter, we give a motivation for the project described in this thesis. We will briefly discuss some statistics about document finding and summarise the research conducted in this area. We conclude the chapter with an overview of the thesis outline.

1.1 Motivation

Today's typical busy schedules make it difficult for people to keep track, organize and search the documents from their own office workplace. Considering the widespread use of paper documents and digital documents, organising the increasing number of documents becomes more demanding. It needs more cognitive effort to manage documents to prevent people ending up with multiple copies of the same document or missing documents. In the case of many documents, if they cannot be found when needed, there can be serious consequences.

Digital documents are typically managed using a computer system while mostly paper documents are organised and managed manually. In the digital world, computer system users have access to different document management systems, to better organize and make use of digital document. In the real world, managing and organizing paper documents has remained a predominantly manual job, leaving users to develop their own strategies for storage and retrieval of the document.

Ironically, often the use of computers compound this problem by making it easier to print a new version of a document that is not found immediately. Additionally, reading paper-based documents is preferable for many as it offers flexibility as read anywhere and easier to mark up (Hinze, McKay, Vanderschantz, Timpany, & Cannigham, 2012). So even the majority of documents may now be digital, we still have many physical documents that we keep and wish to locate.

Thus the flexibility offered by paper-based documents, and wide-spread use necessitates a ‘physical document search engine’. This thesis aims to provide a tool for exactly this purpose.

1.1.1 Cost of Searching for Documents in Offices

Despite the proliferation of electronic document, paper documents have remained an integral medium to our work environment (Sellen & Harper, 2003). Keeping track of or finding documents in one’s own office workplace can be a time-consuming task. When a document goes missing, not only can hours of productivity be lost, but critical timelines may be affected as well. One study on knowledge workers in the USA and UK found that 83% of the knowledge workers believe they waste time each day on issues of document collaboration (Perforce, 2013). 73% of knowledge workers reported wasting work time for looking for files. Due to the pressure of busy work days, 82 % of employees report frustration and even anger (Perforce, 2013).

A study performed by PrincewaterhouseCoopers (PwC) observed that 40% of the work time was spent on looking for a paper document and out of the day, 20% of work time had been spent searching for hard copies of documents. The study further observed that in up to 50% of the time office workers did not find what they wanted (Compulink Management Center, 2007). A study of paper-based filing systems found that on average user makes 19 copies of a document, 7.5% of documents get lost, and 3% are misfiled. Knowledge workers spent up to 15% of their time reading information and up to 50% looking for this information (Ittersum & Spalding, 2005).

1.1.2 Standard Approaches to the Problem

People have come up with few common approaches and practices for addressing the problem of physical document localization.

Good filing. Many people aim to remember the placing of documents in their office and to place similar documents together. Good filing practices are potentially useful but do not seem to work in practice as much as people envision. Relying on the user’s ability to remember the documents location or always to put the documents into their correct files is potentially flawed and raises questions about the long-term success of the practice, in light of the data provided in the previous section.

Digitise documents. Another way to address the problem is to turn paper clutter into searchable online documents called ‘Digitalization’. Digitalization occurs when paper documents are converted into digital files this is accomplished by the document scanning services such as MIXNET. MIXNET, a web-based service for turning paper clutter into searchable online documents. MIXNET is a data conversion and document management company. MIXNET over the years have scanned and converted various documents library deposits (MIXNET, 2014). MIXNET ask users to send all the documents in special evolves and original documents will returned after the scan. Services such as MIXNET may be susceptible to issues of document security and privacy. Highly private, personal documents might be at risk. Previous attempts of converting physical documents into digital, making documents available on different digital platforms for convenient and rapid access have been seen causing several issues such as public access and questionable reliability of anytime access (Hesseldahl , 2009).

Paper-less office. Despite advances in digitalisation of documents, the paperless office is not reality and may not likely ever be completely achieved (Sellen & Harper, 2003). Sellen and Harper found that every country in the Western world uses more paper today, on a per-capita basis, than it did just ten years ago (Sellen & Harper, 2003). We conclude from their observations that even a practice of ‘good filing’ and trust-based digital document management may not be sufficient as it seems that documents will always exists in paper.

We believe therefore that the solution needs to accept the existence of paper documents and work with people’s inability or unwillingness to always file away documents in their right place. Our system for a ‘Human-Centred Workplace’ (HCW) as introduced in this thesis attempts to offer a practical answer to this problem.

1.2 Focus of the Thesis

The focus of this thesis is to provide the freedom of placing documents anywhere in the office while still being able to find them when needed, with the ability to track the location of the physical documents. The link between digital document and printed physical document will be maintained, thus making the physical documents

searchable digitally. This thesis introduces the *Human-Centred Workplace*, a document management system that tracks documents in the office and maintains their links to their digital counterpart.

The solution we propose is to support the management and organization of documents by coupling the physical paper space with the virtual document space. To understand the nature of the physical-virtual link, we researched related work. This thesis is an extension of our previous research, which developed the concept of the Human-centred workplace (Dighe, 2012).

Main concept of this work. Our proposed solution involves building a system to recognize and track documents in the office. The system maintains a link between the identified documents on the desk and those stored in the computer. At the same time, the system keeps a history of the user's recent activities and provides a rich user interface for accessing the information in a timely manner. The link between paper and digital documents is established by printing specially designed 2-dimensional tags, on the specially designed front page that can be identified by using computer vision techniques. These tags encode information about the corresponding digital document. Tracking documents allows for extracting information about the arrangement of papers on the desk and reflecting that information on the document views available to the user. Thereafter, we store information about both paper and electronic documents in addition to the history of user activities in a relational database system. Important information such as what document is printed, when, where and by whom, is saved in the database. The current location of printed documents could simplify the finding task. These components are presented in a rich user interface with multiple views and query methods. Document queries can be performed on both paper and electronic documents. To sum up, the system provides a variety of features that allows efficient management of the user's document space.

Previous research. A previous project on the Human-Centred Workplace (Dighe, 2012), explored background and foundational aspects of this project. For example, we compared the use of Quick Response code with RFID in terms of capacity to store information, and explored the required size for the QR code for reading within the office environment. Our initial experiments with text localization and image comparison gave promising results which are extended in this thesis. The previous

system design had partial success due to the limitations of the cameras and difficulties in reading QR codes from a distance.

1.3 Structure of the Thesis

The structure of this thesis is as follows:

Chapter 1, motivated the thesis and defined its overall goal and structure. In Chapter 2, we study related work performed in the last decade, giving inputs to our need. This chapter explains the related work and the requirements of 'Human-centred workplace' which we can accomplish by extending the scope of studying the related work.

Chapter 3 gives a detailed analysis of the design of the system, and Chapter 4 presents and describes the design and implementation with detailed analysis followed by architecture and changes made in system time to time. Chapter 5, presents an evaluation of the system. In Chapter 6, we discuss our findings and finally we present our conclusions and the future directions for this work.

2. Related Work

This chapter presents research relating to existing systems relevant for this thesis. Much previous work has focused on information management and in particular work related to managing and organizing the documents. The result of these research effort will be presented and discussed in the light of the requirement set by this thesis. The requirements are based on the problem definition provided in Chapter 1.

2.1 System Requirements

In the previous chapter, we discussed the common every day problem user's face for managing and finding their documents. To resolve those problem we propose 'Human-Centred Workplace', a tool to manage and keep track of the physical documents. In keeping the issues and solution for a document organization in discussion, we developed a list of requirements for our paper document managing and finding tool.

We defined five requirements for our system, which we derive from the discussion in Chapter 1.

1. The first requirement is *keeping a record of a printed documents*, many time after printing document, miss placing the document results into document reprinting or document duplication. Keeping track of document allows us to avoid reprinting a document which is already printed and present in the workplace; and thus avoiding duplication of the document.
2. Our next requirement is to *keep track of the location of the physical documents*. In addition creating a linkage between physical document and its digital counterpart will be one off our requirement. Losing a physical document has been a common issue for a user, keeping track of the documents location will allow us to provide the exact location of the document to the user. It will further improve the time normally taken for searching the physical document.
3. The search for physical documents needs to be supported by digital search facilities. This is the main focus of this new software, to support people in their search for documents.

4. Another requirement of HCW is that there should *not be a need of the user to follow any specific order or procedure to be followed*. HCW should cater for user who are not orderly (disciplined) in dealing with documents. Previous approaches for office procedure have shown that many people will just not follow them however sensible these may be.
5. The final requirement of HCW is to have *minimal hardware requirements*, as the hardware used needs to be paid off users it should be utilized by the users in a days to day activity to make it economical, accessible and adaptable it is important to consider less hardware in use.

The presented five requirements of our system will now be compared with previous work conducted related to managing and finding documents. This comparison will allow us to establish the final requirements of our system HCW.

2.2 SOPHYA

SOPHYA (a system for digital control of ordered physical document collection) the first of its kind is a physical document collection system which utilises a wired technology for managing and retrieval of physical documents and artefacts, within the collection (Jervis & Masoodian, 2009). SOPHYA that provides a means of linkage the management of real world document artefact (e.g. folders) with their electronic counterparts, so that document management activities such as locating, filling, retrieving document can be better supported (Jervis & Masoodian, 2011).

In recent years several systems with the uses of RFID (Radio Frequency Identification) have been developed to integrate the management of physical and digital document. Although they can detect the location of a tagged item, such systems were not capable of detecting the particular location and ordering of individual items. Also, in RFID there are limits to the power that can be consumed by the tags thus limiting their functionality. SOPHYA has addresses the limitations and provides flexibility for an orderly collection and document management. (Jervis & Masoodian, 2010).

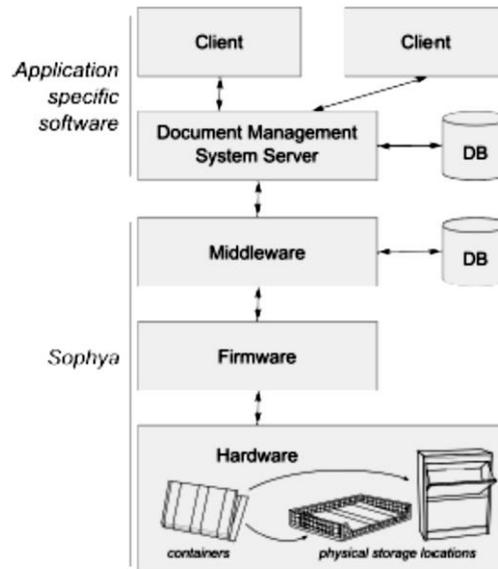


Figure 2.1 Overview of architecture of SOPHYA Reprinted from” SOPHYA: A System for Digital Management of Ordered Physical Document Collections”, by M. Jervis, M. Masoodian, 2010, *Proceedings of the Fourth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '10)*, p. 33-40. Copyright 2010 by ACM. Reprinted with permission.

As shown in Figure 2.1, the system is divided into three components hardware, firmware and middleware. The hardware component consists of physical document containers for holding folders which can be placed in the different locations in the user environment (e.g. In Filing cabinets or on shelves). The connection between the container and the location of the container is established with electronic circuitry. Each folder has allowed an allocated physical location within a container. Both the containers and their physical location have a unique ID for the identification of objects within the container. A LED (Light-Emitting Diode) on the surface of the container act as a user interface to indicate that the required document is in the container. Firmware embedded in the physical storage location communicates (e.g. read IDs of the containers and controls the user interface) with the container. The firmware also communicates with the middleware, that maintains simple database that keeps track of information in the container and the physical location of the container (Jervis & Masoodian, 2010). In SOPHYA the wired communication supplies power to the electronic components thus allowing more functionality than Radio frequency identification (RFID). When working SOPHYA provides a two-way interaction between the physical and digital worlds. From the physical to digital

interaction, SOPHYA is able to communicate the location of a given document (shown in Figure 2.2).

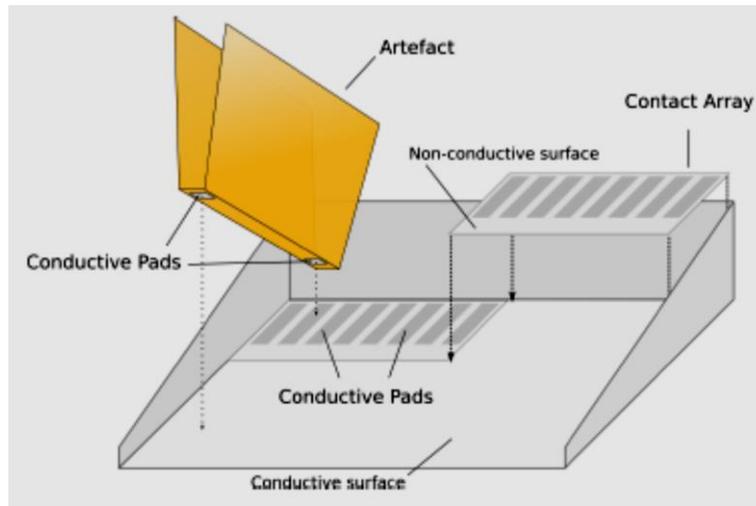


Figure 2.2 Design of the contacts for communication between artefacts and storage locations
Reprinted from "SOPHYA: A System for Digital Management of Ordered Physical Document Collections", by M. Jervis, M. Masoodian, 2010, *Proceedings of the Fourth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '10)*, p. 33-40. Copyright 2010 by ACM. Reprinted with permission.

However the system has a number of limitations. First the documents still have to be placed in a particular container to be located so it does not provide flexibility and a particular procedure need to be used. Secondly, metadata need to be entered and maintained manually and this is time consuming. In a Human-Centred Workplace (HCW) the approach is to support real life situation where people can deposit their physical documents anywhere in the office and be able to recover them easily. In HCW one of our requirement is digital search of the document, SOPHYA matches the requirement but only the document placed in the container will be searched.

2.3 The Fused Library

The Fused Library is a method using RFID (Radio Frequency Identification) technique, that provides the ability to link physical items with content in a digital library (Buchanan & Pearson, 2010). The motivation of Fused Library was to explore in what way physical and electronic documents can co-exist and complement each other (Buchanan, 2010).

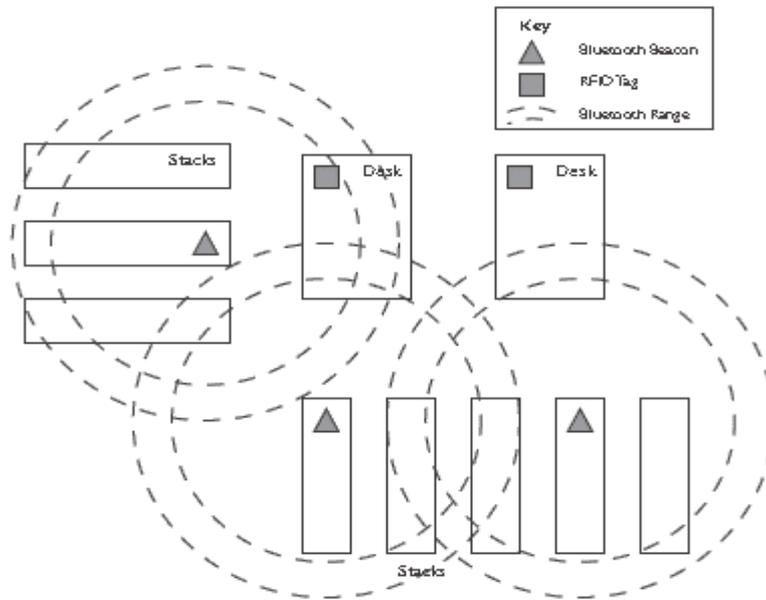


Figure 2.3 Physical infrastructure of Fused Library Reprinted from” The fused library: Integrating digital and physical libraries with location - aware sensors”, by G. Buchannan, 2010, *Proceedings of the 10th annual joint conference on Digital Libraries (JCDL'10)*, p. 273-282. Copyright 2010 by ACM.

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Figure 2.3 shows the physical infrastructure of Fused Library. The fused library system identifies user’s context and on the basis of their location provides the useful related information to them on their laptop by using software platform. In working of Fused Library Radio Frequency Identification (RFID) tags are used for information gathering. The RFID tag is placed underneath a desk, where a laptop-based RFID reader can detect the tag when placed on the top of the table. The laptop location was recognized as the user’s physical location. Depending upon the user’s current location, the library catalogue server will present them or the user with a tailored home page including a quick link to related useful sections in that location. Further the user can query the library catalogue and it will highlight the books near the user’s location (Buchanan & Pearson, 2010).

Figure 2.4 shows the architecture for Fused Library. The figure shows a traditional library system (centre), that mediates access to an external catalogue (right) and delivers the content to the users computers operates by users (left). The hierarchy used is same for both physical and digital items.

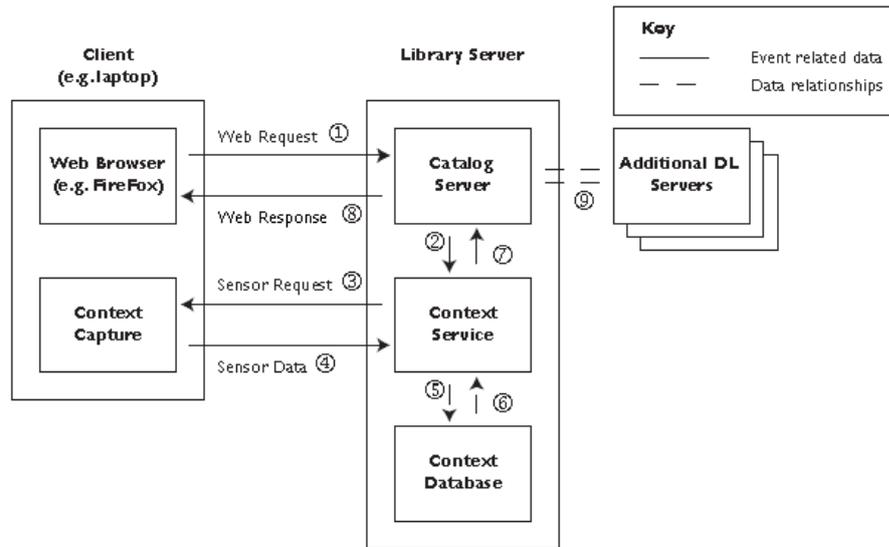


Figure 2.4 Architecture of Fused Library Reprinted from” The fused library: Integrating digital and physical libraries with location - aware sensors”, by G. Buchannan, 2010, *Proceedings of the 10th annual joint conference on Digital Libraries (JCDL'10)*, p. 273-282. Copyright 2010 by ACM. Reprinted with permission.

The Fused Library is a library-based system, but it meets our requirements like tracking down the location of the user and the document. However it does not keep track of the printed document. The fused Library also assistant in document tracking by providing the documents nearby object to user and even further by using ambient media. However not every office will be organized as the library so locating the physical and digital object across the workplace will be the actual challenging job which hasn't covered or worked out in the 'Fused Library.'

2.4 Limpid Desk

Limpid Desk allows a user to visually access a lower layer document without the top layer of a physical document needs to be removed (Iwai & Sato, 2006). The Limpid Desk transparentizes the upper layer of the document, that is, “the appearances of the upper layer documents is presented as if they are transparent”. The user therefore can intuitively find the desired document even if it is hidden under the document stack. The hardware used in Limpid Desk includes Projector, Camera and thermo camera (shown in Figure 2.5). The transparentizing is accomplished by projecting a distractive pattern of light, and projecting the background image to the projection object. Transparentization in Limpid Desk project is achieved by

combining the surface of the lower layer document under the top layer of the paper document (Iwai & Sato, 2006).

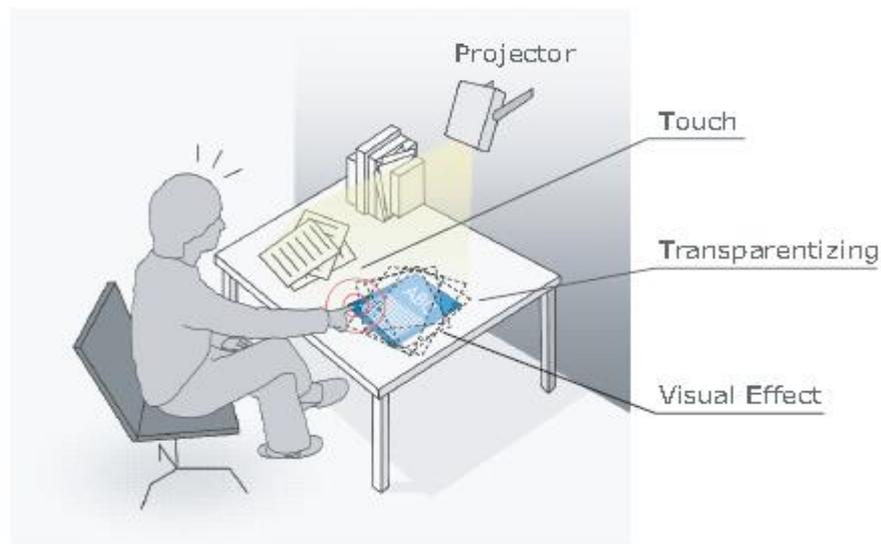


Figure 2.5 Conceptual idea of Limpid Desk Reprinted from” Limpid Desk: See-Through Access to Disorderly Desktop in Projection-Based Mixed Reality”, by D. Iwai, K. Sato, 2006, *Proceedings of the ACM Symposium on Virtual Reality Software and Technology, VRST 2006*, p. 112-115. Copyright 2006 by ACM. Reprinted with permission.

In transparentizing two different visual effects have been used. The capacity of the top layer is gradually reduced such that it appears transparentized. Secondly, a visual effect is used represent the sheet number of virtually exposed documents.

In the Limpid Desk, physical document search interaction techniques are preferred. The Thermo camera (as shown in Figure 2.6) takes desktop images ‘warmed by user touch’, achieved through thermo-graphical colour touch sensing methods. The user does not need to wear gloves or use any of the equipment such as a styluses. When the user touches a document on the desk the system detects the touch and then the upper layer document is virtually transparentized by projection.

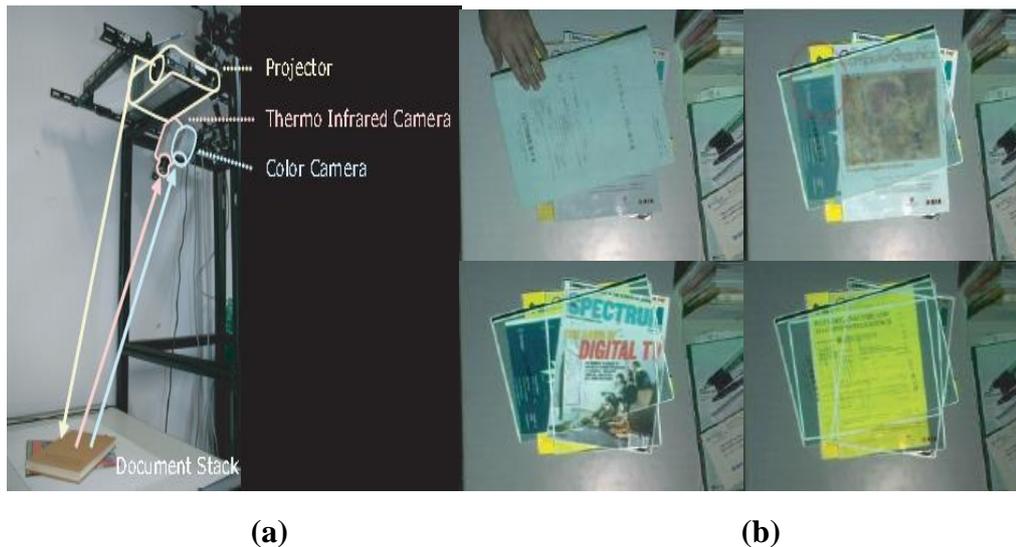


Figure 2.6 (a) Outlook of Limpid Desk (b) Interaction with Limpid Desk Reprinted from” Limpid Desk: See-Through Access to Disorderly Desktop in Projection-Based Mixed Reality”, by D. Iwai, K. Sato, 2006, *Proceedings of the ACM Symposium on Virtual Reality Software and Technology, VRST 2006*, p. 112-115. Copyright 2006 by ACM. Reprinted with permission.

Figure 2.6 shows the outlook of Limpid Desk system and through pictures describes the interaction of user with the Limpid Desk. In Limpid Desk, functions such as ‘Stack Browse’ allow the user to find documents on the stack. In stack browse, the upper layer documents are transparentized one by one to the bottom of the stack. The effect of a combination of fade out and retraining document frame means that the user can browse all the documents in the stack till they find their document.

The Limpid Desk system meets our requirement of making the access and managing of the document simple and less time consuming. As the user can visually access a lower layer document without removing the document on the top, the limpид desk is a possible solution to the problem of finding a document in a pile.

2.5 Paperspace

PaperSpace is a document management system that uses computer vision to track documents on the user desk, then maintains a link between the printed document and its digital counterpart. PaperSpace supports the tracking of multiple documents in real time. However this method of document management is restricted to the academic arena and research area (Sallam, 2006).

In every - day working with paper it is a common situation for people to resort to reprinting of the paper already on their desk as they are not sure whether the paper has already been printed or because would take a long time to locate the document. As a solution to the issue, PaperSpace proposes a system to support managing and organizing physical document space by coupling the physical and virtual space with the virtual document space (Smith, Long, Lung, Anwar, & Subramanian, 2006).

The PaperSpace working architecture is based on tracking 2D identity and operation codes printed in the margins of each page of the document. In PaperSpace when users print a digital document, a special 2D barcode is created and placed in the margin of the document (Sallam, 2006).

The PaperSpace system uses a medium resolution webcam to track the papers around. The system features other functionalities such as capturing and parsing gestured operation performed on the command bar. In PaperSpace, information regarding the identity and location of the paper, is passed from the vision system (camera system) to tracking system. The tracking system builds a coherent understanding of each paper's location (Smith, Long, Lung, Anwar, & Subramanian, 2006).

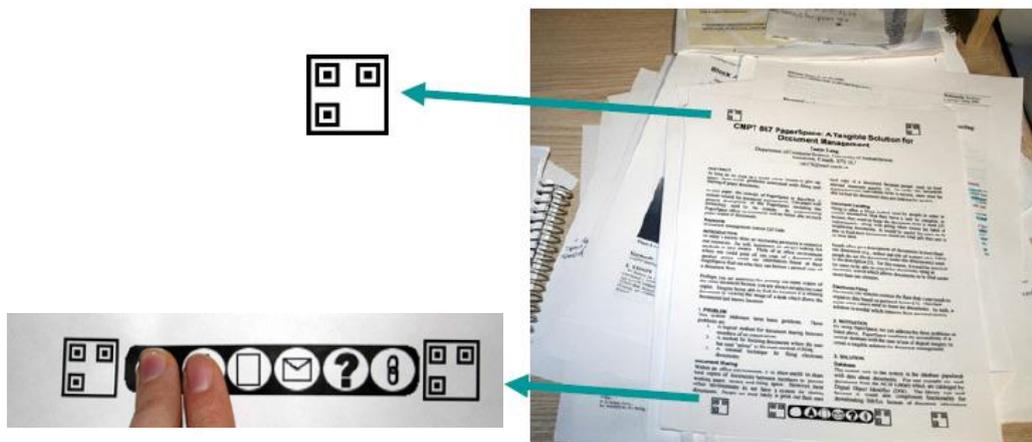


Figure 2.7 Example of printed paper and command bar at the bottom of the paper Reprinted from” PaperSpace: A System for Managing Digital and Paper Documents”, by J. Smith, J. Long, T. Lung, M. Anwar and S. Subramanian, 2006, Proceedings of the CHI '06 Extended Abstracts on Human Factors in Computing Systems (CHI EA '06), p. 1343-1348. Copyright 2006 by ACM. Reprinted with permission.

Along with the identity and location tracking, PaperSpace presents a command bar as shown in Figure 2.7.

The command bar is a static image that provides functions such as link and email forestablishing communication between the paper document and its digital counterpart. A command system allows users to manipulate digital documents directly using their printouts (Smith, Long, Lung, Anwar, & Subramanian, 2006).

In PaperSpace, system users are given the location information but visual assistance or any assistance to minimize the search to find the paper is not prototyped. Location tracking is highly dependent on the tracking modules coherent mapping of the data (Smith, Long, Lung, Anwar, & Subramanian, 2006).

2.6 Video-Based Document Tracking

Video-Based Document Tracking is a tool for tracking paper documents on a desk and automatically linking them to the corresponding electronic documents (Kim, Seitz, & Agarwala, 2004). A video camera is used in the operation.

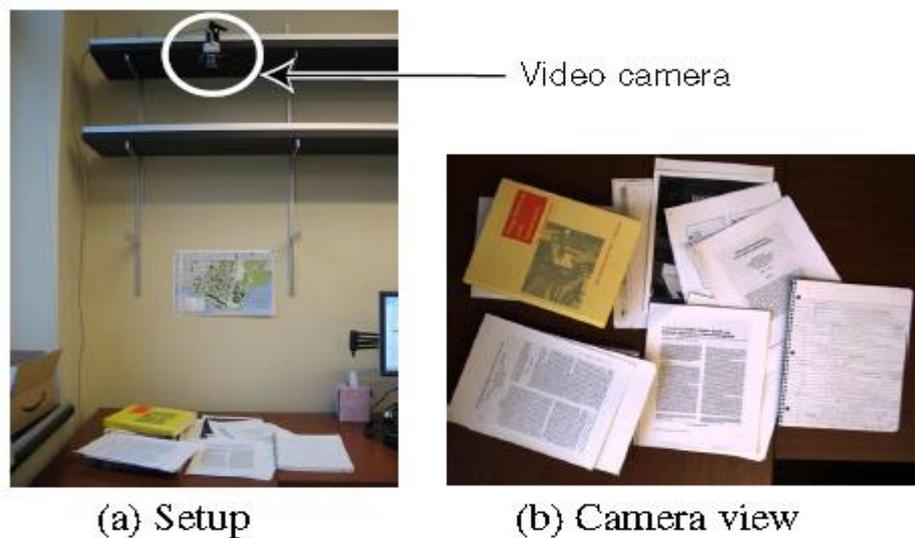


Figure 2.8 Video Document Tracking Overview Reprinted from “Video-based Document Tracking: Unifying Your Physical and Electronic Desktops”, by J. Kim, S. Seitz and M. Agarwala, 2004, *Proceedings of the 17th annual ACM symposium on User interface software and technology (UIST '04)*, p. 99-107. Copyright 2004 by ACM. Reprinted with permission.

Users commonly faces, the issues such as decoupling of documents physical and digital form that makes difficult to take advantages of both digital and physical media.

As shown in Figure 2.8, the camera is mounted above the desk to capture and track the document movements. The video captured is analysed using a computer vision technique with document recognition that enables to link every paper document on the desk with its electronic copy. In the system the document can be searched using keywords typed into the system. Alternatively, a user can search the document stack in the remote desktop interface by clicking and dragging on the image of the desk.

A positive feature of the system is its simplicity. It does not involve the tags or special readers. The system is designed on the basis of some assumptions such as at a time only one document can be placed or removed from the stack for better tracking ability.

However the system is designed so that only one document can be placed or removed from the stack. The system also assumes that the every document placed on the desk is unique. Assumptions restricts the user interface and it highlights the need of assumptions need to be relaxed in future systems.

2.7 DocuDesk

DocuDesk, a system based on interactive desk technology, has been designed to address the challenge of establishing a relationship between the digital and physical (paper) document. Commonly people face challenges such as loosing physical document and forgetting the path of digital documents. DocuDesk is an attempt to address these challenges by establishing the placement of paper document on the desk to initiate task rehydration and by capturing digital copies of user's paper document as they kept on the desk (Everitt, Morris, Bush, & Wilson, 2008).

As shown in Figure 2.9, The DocuDesk system emphasis a user's existing system (PC set-up) with the addition of interactive desk and overhead video IR (Infra-Red) camera. Each paper placed on the DocuDesk is observed by the system's camera. In DocuDesk there are two ways of linking the document with its digital counterpart. First, it has 2D barcode, their barcode can be used to establish the link.

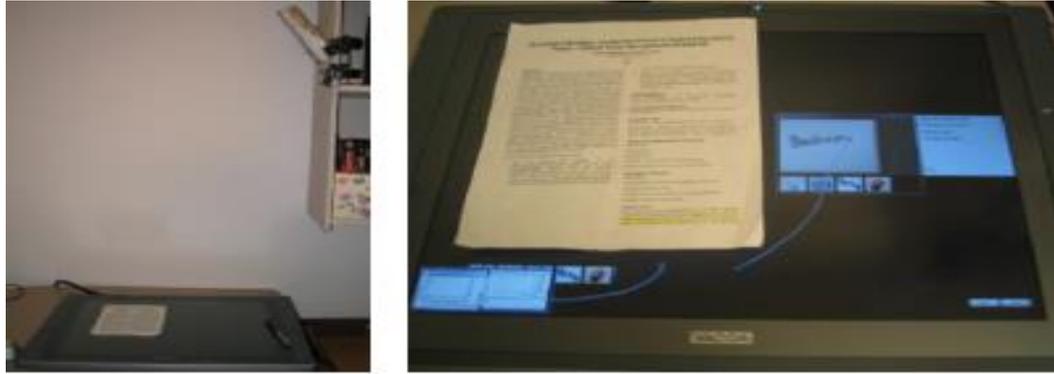


Figure 2.9 The DocuDesk Reprinted from “DocuDesk: An Interactive Surface for Creating and Rehydrating Many-to-Many Linkages Among Paper and Digital Documents”, by M. Everitt, R. Morris, B. Bush and D. Wilson, 2004, *Proceedings of the 3rd IEEE International Workshop on Horizontal Interactive Human Computer Systems, TABLETOP 2008*, p. 25-28. Copyright 2008 by IEEE. Reprinted with permission

Second, the image captured by the camera above a desk records an image of the document and with image recognition link with the digital counterpart will be created.

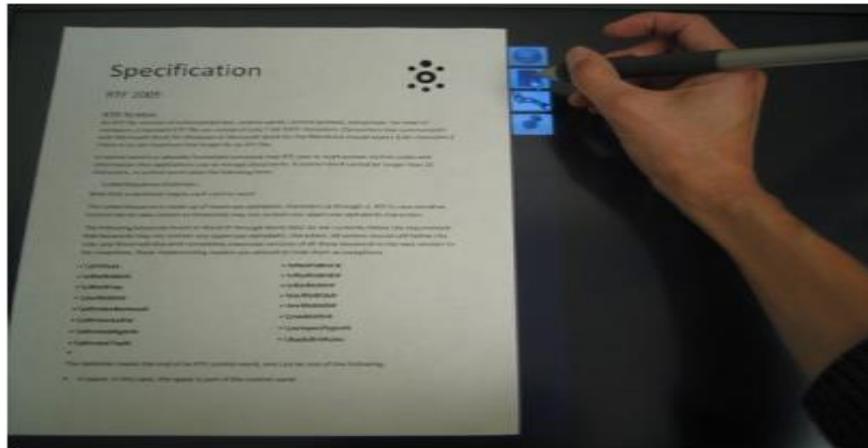


Figure 2.10 User interaction with DocuDesk Reprinted from “DocuDesk: An Interactive Surface for Creating and Rehydrating Many-to-Many Linkages Among Paper and Digital Documents”, by M. Everitt, R. Morris, B. Bush and D. Wilson, 2004, *Proceedings of the 3rd IEEE International Workshop on Horizontal Interactive Human Computer Systems, TABLETOP 2008*, p. 25-28. Copyright 2008 by IEEE. Reprinted with permission

On placing the document on the DocuDesk the user is given various options such as email, open and link (see Figure 2.10). If the Email option is selected, the system opens a new email message containing the papers digital version as an attachment. If the digital document option open is selected thus opens up the digital version of the physical document on the desk.

The ability to provide link to two different form of media on one desk is a unique and useful feature. DocuDesk facilitates different tasks involving digital and a paper document and going beyond further it provides many to many relation among the digital and physical documents.

2.8 Conclusions

The analysis of related work has considered six projects: SOPHYA (Section 2.2), Fused Library (Section 2.3), Lipid Desk (Section 2.4), PaperSpace (Section 2.5), Video Document Tracker (Section 2.6) and DocuDesk (Section 2.7). The work was analysed and weighted in relation to our requirements for keeping record and re-finding of printed documents. (1) Tracking documents location, (2) keeping record of printed documents, (3) providing digital search, (4) No order to follow and (5) No special hardware required. Table 2.1 summarises our observation and we note none of the systems fits all the requirements.

Table 2.1 Summary of comparison between requirements and related work

<i>Work</i>	<i>Requirement</i>				
	Keeps Record of Printed Document	Tracking Documents Location	Digital Search	No Order to Follow	No Special Hardware
<i>SOPHYA</i>		✓	✓		
<i>Fused Library</i>		✓	✓		
<i>Limpid Desk</i>				✓	
<i>PaperSpace</i>	✓	✓	✓		✓
<i>Document Video Tracking</i>		✓	✓	✓	✓
<i>DocuDesk</i>			✓		

Though SOPHYA does not keep record of document activity such as document printing but keeps track of document's physical location, by asking users to put the documents in a special container (that is, a predefined structure have to be followed). The container uses RFID tags, and these tags and a particular stand to read the RFID tags states the special hardware requirement. Thus, proving SOPHYA does not match with our requirements such as keeping record of document, no order to follow and no special hardware requirement.

The Fused Library system which uses RFID tags and tag sensor for document locating, dose meet our requirements such as tracking the location of the document and providing digital search of physical documents. Further it is observed that Fused Library does not need a user to follow a particular order for using the system. Fused Library dose match with few of our requirements but it does not accommodate users need such as keeping track of printed document. The use of special hardware such as RFID tags and tag sensor's does not meet our requirement of minimum or no special hardware utilization.

In another work Limpid Desk full fills our requirement such as no order to follow for using the system. In Limpid desk, users are not given functionality such as keep track of the document print, location tracking but it support digital search through the use of virtual transparent technology that allows user to scan the documents in the pile. Further we observed, Limpid Desk does not provide location of the document, instead asks users manually search for the document with use of transparentizing the top layer of the documents.

Document Tracking System does match with our requirements such as keeping track of the document and providing location of the document with the use of minimum hardware requirement such as a camera. Document Tracking System which is mainly designed to create a link between digital and physical documents but do not keep the track of the printed document making user vulnerable to reprint the same document. In the system user is not asked to follow a particular order gives the user mobility and freedom of placing the document anywhere user wants to.

DocuDesk, built with an intention to establish the relation between physical document and its digital counter part see the success. In comparison with our system requirement DocuDesk match with only one requirement of allowing digital search.

System show unique features for establish linkage between two document medias. The special hardware requirement, a DocuDesk can restrict its use.

PaperSpace, match with our requirements such as Tracking the document, keeping record of printed document, but PaperSpace does not provide an image of the document location. Further, it is assumed that at every time only one paper will be added to the workplace. Thus making system to have a certain order to follow.

We observe that none of the analysed systems are designed to keep the track of the document user have printed. All the observed systems fail to provide a link between digital and physical space for searching the physical document. Further it is observed that, most of the systems do not provide user a freedom of placing documents anywhere in the workplace, thus restricting the mobility. In some systems the use of special hardware such as containers, RFID tags, and special designed desk further restricts user's mobility and free use of system in a particular order. It has been observed in the system such as DocuDesk, Document Based Tracking and Limpid Desk the focus is on establishing the link between digital and physical media over tracking the physical document hence those works does not provide a solution for document tracking. Although, some systems have some similar aspects of the HCW but none of them can fulfil all HCW requirements to manage and find the physical documents.

3. Conceptual Design of HCW

This chapter presents the design for our system, based on the requirements discussed and determined in Chapter 2. This chapter provides an overview on how the design components are related to each other and presents details of the architecture of the system and each of the components. The chapter begins by presenting our idea of using the Quick Response (QR code) (Section 3.1) then follows with a scenario (Section 3.2). Finally, its design and architecture are discussed with its components: Document Manager, Document Search, and Document Tracker (Section 3.3).

3.1 Idea of using QR codes

The QR code is proposed as a document identification tag in the Human-Centred Workplace (HCW) system. The main reasons of using QR code is the flexibility, an ease to generate on the document and the user does not need of user involvement in deploying tag on the document are among the main reasons to use QR code as a passive tag. Although the use of an active tag Radio Frequency Identification (RFID) tag are widely accepted in most of the ‘without touch’ information retrieval and object localization systems. These has would not fulfil HCW system requirement of keeping an application easy to use and economical with hardware requirements.

The QR code on each document will be printed on a specially designed page to be attached to the front of each document. The QR code will contain the relevant information to the printed document and used for its identification.

3.1.1 Specification of the Visual 2- D dimension ID tags

The QR code 2-D dimensional visual codes, enclosed information in 2D dimension will be automatically generated by the system whenever a paper is printed and added to the user’s workplace environment. Figure 3.1 illustrates the internal structure of QR code.

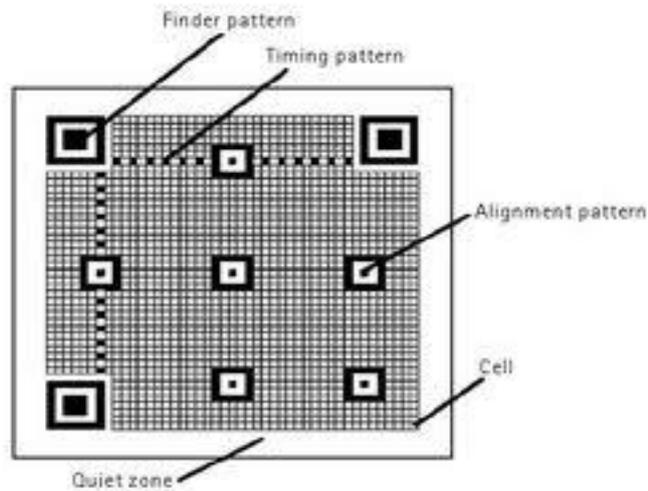


Figure 3.1 QR code structure

Finder Pattern (Position detection pattern)

The Finder Pattern is used to detect position, the size and the angle of the symbol. This finder can be detected from all 360⁰ direction.

In QR code, the finder pattern enables high speed reading. The Two dimensional symbols generally contain much more data than liner (1D symbols) symbols and therefore requires longer data processing time and is a more complex process (Soon, 2008).

Alignment Pattern

As distortion in the QR code is highly likely; an alignment pattern works to correct distortion of the QR code. The black cell in the alignment pattern makes it easier to detect the central coordinate of the alignment pattern.

Timing Pattern

This pattern on QR code symbol is used for correcting the central co-ordinate of the data cell when the symbol is distorted or when there is an error in the cell pitch. The timing pattern identifies the central co-ordinate of each cell in the QR code with a black and white pattern arranged alternatively. Timing pattern can be seen both horizontal and vertically on the symbol.

Quiet Zone

Quiet zone is the marginal space around the QR code. Normally white colour is used for quiet zone space but colours can be used. Quiet zone space is necessary for

reading the QR code. Quiet zone makes it easier to read the symbol read by the sensor. Four or more cells are necessary to form a quiet zone (Soon, 2008).

Data Area

The data area is represented by the grey area in the Figure 3.1. The data is encoded in binary form (numbers 0 and 1), and converted into black and white cells.

3.1.2 QR code specifications

QR code have certain specifications those such as size, type of information and the error correction functionality.

Symbol Size

The size of QR code depends on data volume to be stored and the reading method. Normally, the size of a QR code symbol is incremented by four cells in both vertical and horizontal directions like 21 x 21 cells, 25 x 25 cells, and 29 x 29 cells. In total there are 49 size types with the maximum size set to 177 x 177 cells.

Information Type

In QR code it is possible to store various types of data such as numerical character, alphabets, signs, kanji, hiragana, katakana, different control signs and even images. The character set should be supported by JISO/IEC 646 and ISO/IEC 10646. As noted earlier QR code can store up to 7,000 characters in one QR code symbol.

Error correction functionality

QR code has an Error correction functionality for restoring data and this error correction blocks is fixed inside the data area. Error correction uses a special mathematical technique commonly known as the 'Reed-Solomon' method. The method can be used for error correction readings of QR code due to poor printing are damaged to some extent. The user can select different error correction levels according to the desire of correction required while generating QR code (see Table 3.1).

Table 3.1 The QR code Error correction efficiency, Reprinted from” QR Code”, by T. Soon, 2008, *Synthesis Journal*, p. 59 - 78. Copyright 2008 by ACM. Reprinted with permission.

Error Correction Efficiency	
Level	Correction
L	Approx. 7% of the Symbol area restored at maximum.
M	Approx. 15% of the symbol area restore at maximum.
Q	Approx. 20% of the symbol are restored at maximum.
H	Approx. 30% of the symbol are restored at maximum.

3.1.3 Encoding

In the QR code the message data is placed from right to left in a zigzag pattern as shown in Table 3.2.

Table 3.2 The QR code encoding modes, Reprinted from” QR Code”, by T. Soon, 2008, *Synthesis Journal*, p. 59 - 78. Copyright 2008 by ACM. Reprinted with permission.

Indicator	Meaning
0001	Numeric encoding (10 bits per digits)
0010	Alphanumeric encoding (11 bits per 2 characters)
0100	Byte encoding (8 bits per character)
1000	Kanji encoding (13 bits per character)
0111	Extended Channel Interpretation
0000	End of message

In the large symbol, QR code is complicated by the presence of the alignment pattern and the use of multiple interrelated error correction blocks. In QR code, four bit indication blocks are used to select the encoding mode. It is observed that an alphanumeric mode stores a message more compactly than the byte mode.

The next section looks at a scenario where QR code could be used in the system development.

3.2 Scenario

Helen is a university lecturer and researcher working on different research projects. She refers to and references scientific papers and publications often printing the documents for later reference. She remembers the references she has used and what she needs to reference for her work but she is not good at organizing her references and documents. Her desk is always covered with printed documents.

Printing Document

It is a regular day for Helen at work, where she is currently working on a conference paper. She finds some relevant research work documents, prints them and places them on the desk. She feels it should be possible for her to record the activity of her printing instead of relying on her memory.

Searching Documents

Helen is looking for a document that she remembers printing a couple of days earlier but even after spending 15 minutes turning her desk upside down she is not able to find it. At this stage, she really wishes she could have some assistance in finding the described printed document quickly and easily.

Reprinting Documents

Failing to find her document Helen has been left with no option but to reprint the document. She then discovers the document on her desk so she now has two copies of same document and feels bad about wasting paper.

In the 'Human-Centred Workplace' (HCW) project, the task is to make Helen's office space more informative and interactive for our user Helen through an easier access to her printed documents and making the process of managing paper documents user centric.

3.3 Conceptual Design

The system architecture provides a structural solution that meets technical and operational requirements of the user (Microsoft, 2014). The software architecture is not only concerned with the structure and behaviour of the system but also with usages, functionality, performance and comprehensibility (Kruchten, 2008).

The particular, this conceptual design address all five requirements as defined in Chapter 2.

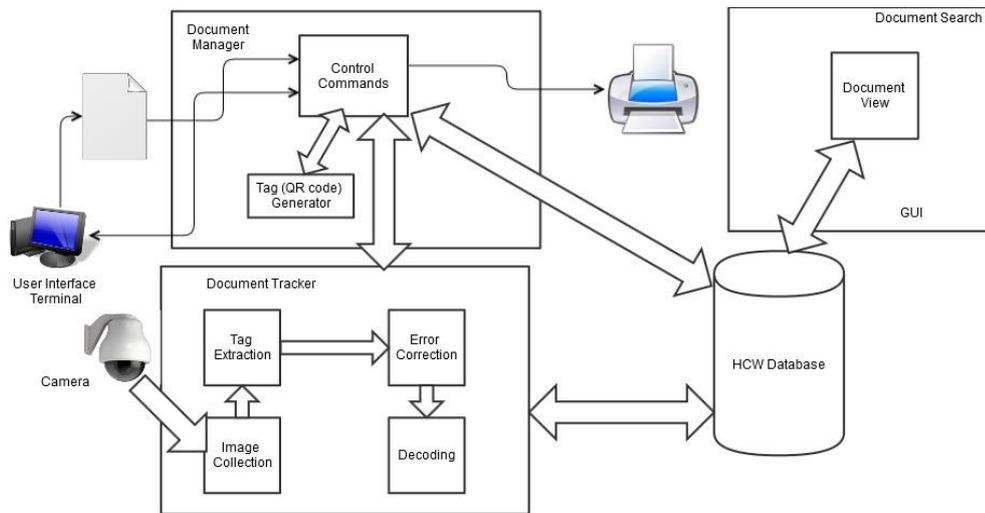


Figure 3.2 Conceptual Architecture

As shown in Figure 3.2, the system architecture consist of three parts 1) Document Manager 2) Document Tracker and 3) Document Search. The external objects involved in the system's conceptual architecture are user interface terminal (Desktop), document printer and document monitoring cameras, all available in user workplace environment.

In summary, the system can be described in the following steps.

System revised in steps one after another

1. User will print the document with unique QR code printed on the front page.
2. The document information will be stored in the database.
3. User will collect the document, keep the document in their workplace.

4. The cameras monitors the workplace, records images (continuous process).
 5. Images taken by cameras will be analysed for QR code, if present QR code will be decoded using QR code reading software.
 6. Each cameras has given a fixed location.
 7. The localization of the document will be based on the camera used to monitor the particular document. Cameras location will be assigned as the documents current location.
- User will use interface for accessing, searching the document and for camera setting.
 - The external entities are Camera, Printer and User interface (Desktop/ Laptop)

3.3.1 Document Manager

In the first component the user prints documents and places them in the workplace. The HCW system recognizes the document and creates an internal structure of document files. Every document is printed with a special 2D tag, quick response code (QR Code). The Document Manager, is responsible for printing the document along with keeping record of the document. As already noted in Section 3.2 HCW propose to print the 2D tag on the new page as a front page. The QR code tag will store the information taken from internal content of the document. The system focuses on gathering information in relation to the document in print such as date of printing, how many times the document has been printed, and for what purpose. Keeping track of the document record and storing information on the database allows the document manger to perform 'Document Duplication Check'. Document Duplication Check, performed on every document requested to print. This is to avoid duplicating documents. Along, with gathering document data automatically, the system request users to enter an input of data as a document information such as printing purpose will be used a clue to remind user more about the document.

3.3.2 Document Tracker

The document tracking component focuses on document identification and tracking the documents location. This involves the use of a camera. Cameras are

placed in different locations to cover the area of the user's working environment. The moment of the document is tracked through camera images taken after every two seconds of interval. These images are used for identifying the document and to track the current location. The document tracker components consist of an Image collector and tag extractor. The images taken by the cameras will give input to the Image collector. A QR code tag extractor will be used to detect the QR code from an image. The QR code decoder extracts the tag on the front page of the document from the images, further decoding the QR code. The decoded QR code and the images from where the QR code is extracted are stored on the database. The decoded information is communicated to the database. This process is ongoing and continues the process of updating images every two seconds. To avoid data overload images are destroyed where no change of information has occurred compared to the immediate last image. External entity, a hardware requirement of HCW system a camera is given a unique identification and this identification is used for tracking the document.

3.3.3 Document Search

The third component of HCW is 'Document Search'. This allows the user to query the system from a user interface for a specific document. Multiple search query methods are offered on the user interface. The user can search for the document by some criteria or can browse the printed documents by keywords.

In HCW, our focus is to make information regarding any printed paper document, with its current location in the area of the user's office available to the user on request. Moreover, our requirement is to find the required information related to the printed document and then localize the same document. Further, we aim to provide a link between the search paper document and its digital counterpart.

3.4 Summary

Chapter is concentrated on the conceptual design of our HCW system. First of all the conceptual architecture explains how to manage physical document, in a bid to locate the paper document. Earlier in the chapter we present the use of QR code the further we describe user scenario which are used to present giving a physical overview of the system. In Section 3.3, the conceptual design shows how HCW links two different document media, digital documents and its physical counterpart.

Further in section, elaborating the architecture of HCW for managing and finding the physical document is divided in three main components; Document Manager: to print and keeping record of the document, Document Tracker: performs document identification and location tracking, Document Search: provides a user interface for a document search.

In the next chapter we will introduce our system implementation based on the results of this design chapter.

4. HCW Implementation

Chapter 4 sheds light on the implementation of our HCW system. The conceptual architecture of the system takes account of the system, the user of the system, the local storage and the user interface of HCW.

In the last chapter we presented the system design and the layers of the system architecture. The scenario gave the background to understand the conceptual work. This chapter describes the implementation of the complete system. Before each system component is outlined the implementation environment and technologies will be presented. Later in the chapter, we show the user interface and describe the user's interaction with the HCW system.

4.1 Technology Used

In this section, we discuss the technologies we propose to use in the implementation of HCW. The technologies are identified, chosen on the basis of requirements of our system's conceptual design described in Section 3.3.

4.1.1 Finding and decoding tags

The document tracker component of HCW receives a full image of the desk surface which has been captured by either of the cameras. The aim is to locate and decode the QR code ID to recognize the papers on the desk. The task of QR code detection and reading the QR code is performed within two to three seconds. The image processing is minimized by simple but effective algorithm.

The following are the steps describing the algorithm used for image processing.

- The image is converted to a grey scale image. This action reduces the size of data to be processed.
- In image an edge is obtained by applying the canny operation. This step results in a binary image consisting a black background and a white line representing the object edge.
- The barcode component is extracted from the edge image.
- The decoder reads the data block from then barcode in order and groups the bits in a single message.

- The decoded message is sent to the Document Manger (see Section 3.3.1) which will check the database for a matching document.

4.1.2 Hardware Requirement

In this section, we present the use of external entities; our systems hardware requirement.

4.1.2.1 Camera

In Section 3.3.2, we propose to use a camera for document tracking. High resolution camera with wireless connectivity match our requirement. The high resolution allows more range and distance to cover, were wireless connectivity provides no restriction on mobility of camera. The camera will be placed in the workplace, monitoring the document moment and further passing the data to HCW for processing.

4.1.2.2 Printer

Printer requirement is not specific and any ordinary printer can be used. In this HCW prototype, we propose to use HP laser jet printer. The printer will be used for printing the document along with printing the QR code a passive tag on the document.

4.1.3 Software requirement

In this section, we present the software packages we propose to use in the development of our system, HCW.

4.1.3.1 Stroke Scribe

The stroke scribe is a program designed for a manual or an automatic generation of barcode. It can be integrated with console applications such as Microsoft office and Microsoft visual studio (C#) (StrokeScribe, 2008-2014).

We propose to use Stroke Scribe SDK library (StrokeScribe, 2013) for generation of QR code on the document. The SDK will be integrated with HCW system to create the QR tag, the QR tag will be stored in the image format, to be used later on the document.

4.1.3.2 Aspose

In attempt to read QR code in Image Aspose.Barcode SDK (Aspose, 2014) for .Net is used. Aspose.Barcode is a barcode recognition component written in managed C# (Aspose, 2002-2014). The component allows to quickly and easily recognize, decode the QR code from image provided by the cameras.

4.1.3.3 PrinterPlusPlus

Printer++ is a windows virtual printer driver (Printer++, 2013). Printer++ allows to print from document viewer (PDF, word etc.) files and then have the job sent to a printer++ (Printer++, 2013). The job is tailored to the HCW system requirements.

4.2 System deployment

This section provides an overview of the active process, which in HCW ranges from physical document management to tracking and monitoring user's physical documents.

Deployment diagram depicts a static view of the run-time configuration of processing nodes and components that run on those nodes (Ambler, 2014). Deployment diagram presents and describes the relation between hardware of the system, the software that is installed on hardware and the middleware (Ambler, 2014).

As shown in Figure 4.1, the HCW consists of two nodes. The first node is HCW user environment and other node is HCW server. HCW user environment consists of three device nodes present in the user workplace environment, the devices are Desktop, Printer and Cameras. The user interface between user and system is a desktop, Dell OptiPlex 9020 Intel® core™ i7-4770 CPU 3.40 GHz with 16 GB RAM memory capacity. The printer used for printing user document is HP laser Jet 4350n. Two cameras used with purpose to keep track of the document are 2.0 web camera and megapixel IP camera respectively.

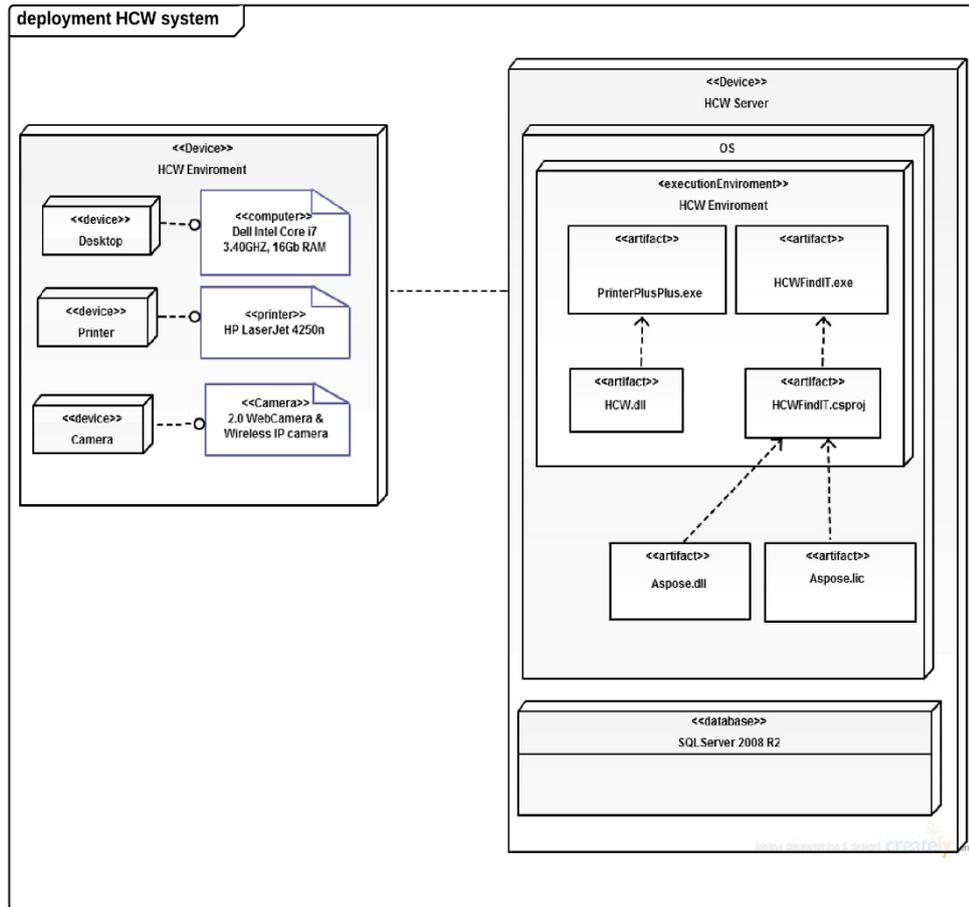


Figure 4.1 Deployment diagram of HCW

The operating system on where the HCW system is running is Windows 7. The execution environment used for HCW is Microsoft .net with language used is C#. Two artefacts are designed, First artefact is Document Manager, and second is Document Tracker. The artefact HCW.dll is designed to perform functions such as printing document with tag, storing document information and document duplication check. Use of PrinterPlusPlus.exe (Printer++, 2013) virtual printer driver application allows HCW to deploy Document Manager and use it from any document editor on viewer, initiating the Document Manger application.

4.2.1 Artefact 1: Document Manager

Initializing PrinterPlusPlus

Printer++ (Section 4.1.3.3) is a virtual printer driver we propose to use. In the beginning we initiate the Printer++ process to take user printing request, which

collects the printing job and converts the document file to .ps (post scrip) file. The .ps version of the file will be forwarded to the HCW application. For further operations such as reading content of the file .ps file will be converted and saved as .pdf file.

```
public PrinterPlusPlusSDK.ProcessResult Process(string key, string psfilename)
{
    var pdfFilename = System.IO.Path.GetTempFileName();
    ConvertPSToPDF(psfilename, pdfFilename);
    return new ProcessResult();
}
```

Printing document with Passive tag

After receiving print request, along with keep record of the document information on the database, the document will be assigned a unique passive tag on a specially formatted front page that will be attached to the document (shown in Figure 4.2).

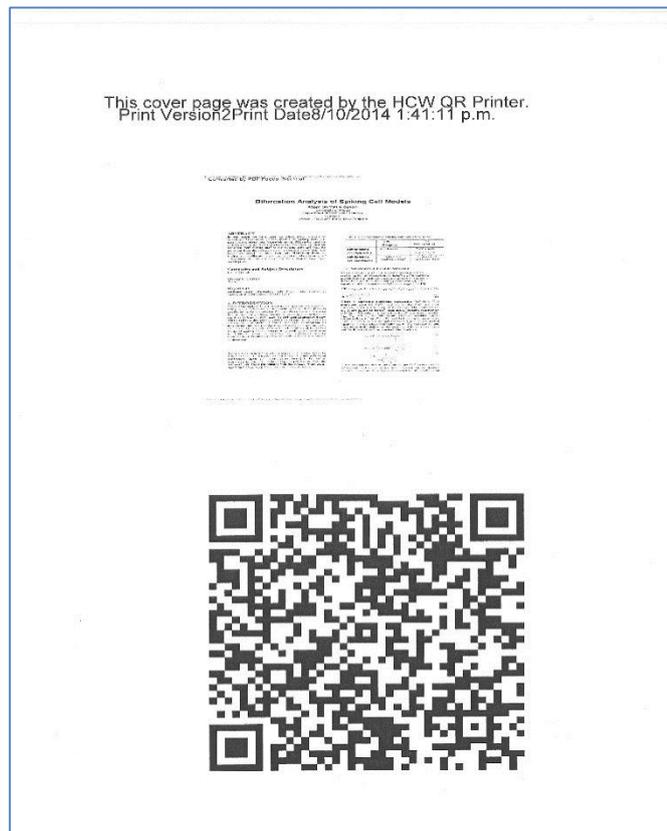


Figure 4.2 Specially-designed front page of the document with QR code

The identification information will be taken from the content of the document; a number of lines will be chosen from the document for an input to the QR code tag of the document.

Following lines of code describes the method of encoding the text into the QR code, we used STROKE Scribe (StrokeScribe, 2013) as a tool to generate QR code on the document.

```
//-----Range of line from .doc file to be use as QR code text -----  
  
int NumberOfLines = 12;  
  
string totaltext = "";  
  
StrokeScribeClass ss;  
  
ss = new StrokeScribeClass();  
  
ss.Alphabet = enumAlphabet.QRCODE;  
  
ss.QrMinVersion = 4;  
  
ss.ECI = 0;  
  
ss.QrECL = enumQR_ECL.M;  
  
for (int i = 6; i < NumberOfLines; i++)  
{  
totaltext += "\r\n " + docs.Paragraphs[i].Range.Text.ToString();  
}
```

The range of input given in above code is from line number 6 to 12. However, as each document has its own design the blank space may occur between a different ranges of lines so it we wrote a case to locate the blank content so the user can assign another line range as an input for QR code tag.

```
// detecting the white space  
  
if (string.IsNullOrEmpty(totaltext))  
{  
string inf = Microsoft.VisualBasic.Interaction.InputBox("For file identification, please enter the range  
of text lines from the document Example: Range Line 10 to Line 12 Range from = 10 Range to 12",  
"Range from?");  
  
string inf1 = Microsoft.VisualBasic.Interaction.InputBox("Range", "Range to?");
```

```

int NumberOfLinesAt2 = Convert.ToInt32(inf1);

for (int a = Convert.ToInt32(inf); a < NumberOfLinesAt2; a++)

totaltext += " \r\n " + docs.Paragraphs[a].Range.Text.ToString();

}

```

Document Duplication Check

After creating the document identification tag for every document, HCW will further perform a document duplication check to avoid printing the documents which user have already printed. As shown in the code lines below the identification tag content will be used and compared with the printed documents identification tag bank available in the database. For accurate comparison, white space from the line of text will be deleted and then comparison will be performed using word sort rules.

```

line1 = Regex.Replace(line1, @"\s", "");

line1 = line1.Trim();

line1 = RemoveSpecialCharacters(line1);

Fileid = line1;

ss.Text = line1;

SqlCommand cmd2 = new SqlCommand(" Select * from HCWFinal where FileID=@fileid",ac);

```

If not duplicated, the document will be printed otherwise user will be provided an information of the existing document with its current location, thus avoiding reprinting of the document.

4.2.2 Artefact 2: Document Tracking

Initialize and connecting cameras

In the artefact of document tracking, we propose to use cameras as a device to monitor each document's movement in the workplace. Before each device can be accessed from the code, their interface parameters had to be defined.

First, the device was defined to enable communication with the HCW system. Each device definition is different. The code below shows how to define each device.

```

private FilterInfoCollection webcam;

private FilterInfoCollection webcamNew;

webcam = new FilterInfoCollection(FilterCategory.VideoInputDevice);

```

```

foreach (FilterInfo VideoCaptureDevice in webcam)
{
comboBox1.Items.Add(VideoCaptureDevice.Name);
}

comboBox1.SelectedIndex = 0;

```

Timer calling

One of the requirement of HCW software is to continuous monitor of the document movement in the workplace and for that, we set an interval timer of two seconds to collect data from each camera. The setting will make the cameras take images at every two second and the images will temporarily store on the HCW server and accessed by artefact of Document Tracker.

```

timer1.Interval = 2000;

timer1.Tick += new EventHandler(timer1_Tick);

```

Tracking Documents

For document tracking, the QR codes will be located in the image, we propose to use Aspose barcode reader library (Section 4.1.3.2) to read the QR code from the image.

The result from the QR code decoding will be compared with the document and with their information available in the database. The matching record from the database will be updated with documents location, where document location will be considered the same location as fixed cameras location used for the document tracking.

The code line below shows the method of detecting Aspose library and the using reader function of Aspose.

```

reader = new Aspose.BarCodeRecognition.BarCodeReader(filename, BarCodeReadType.QR);
while (reader.Read())
{
data = reader.GetCodeText();
// reader.Close();
Console.WriteLine("Code Text:" + reader.GetCodeText());
}

```

4.3 Database

In this section, the database of HCW is discussed. We use SQL Server 2008 as the database system. The initial entity relationship diagram (ERD) for HCW will be presented in this section. ERD represents a detailed picture of the entities needed for a system.

4.3.1 First Version of ERD

The first version of the ERD of our system is show in Figure 4.3. It can be seen HCW system has three entities DOCUMENT, CAMERA and REPRINT. Attributes of the each entities have two relationships *is clicked* and *has*.

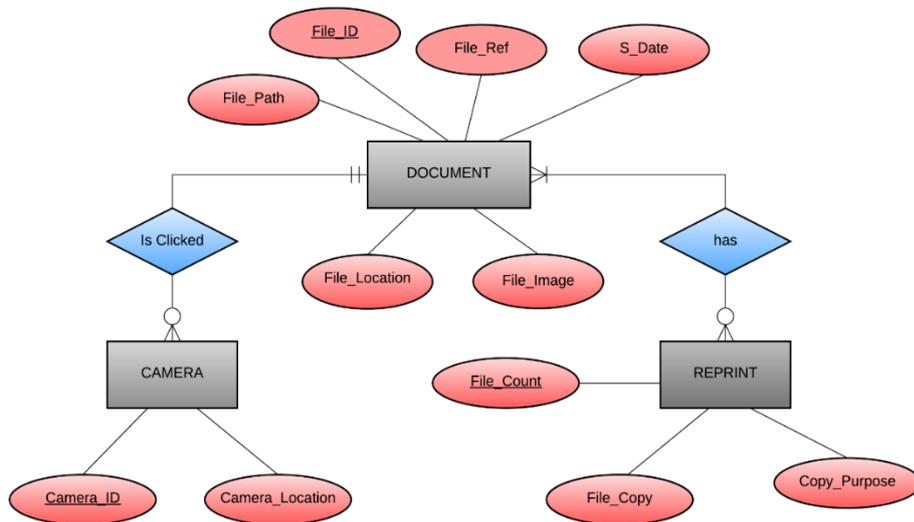


Figure 4.3 The first version ERD of HCW

The document entity has a key attribute File_ID and other file attributes, File_Path, File_Ref, S_Date (system date), File_Location and File_Image (see Table 4.1 for further information about an entities of the first version of the ERD and Table 4.2 for further information on both the key attributes of the same diagram). The attributes of second entity CAMERA is Camera_ID and Camera_Location. The third entity is REPRINT and its attributes are file_Copy, File_Count and File_Purpose.

Table 4.1 shows the entity attribute and their characteristics, description and their primary values. DOCUMENT entity has six attributes and File_ID is a primary key value with numerical variable character (Nvarchar) data type. The value stored in

File_ID is a value created from the internal file content and it is used for document identification. To treat value as unique and to further avoid the document duplication, File_ID is declared as a primary value. File_Path attributes consists the digital path of every document. The other attributes stored are File_Ref, S_Date, File_Location and File_Image. File_Ref and File_Location are of numerical variable character data type. An attribute File_Ref is file text designed by the user's purpose of printing the document. The value for attribute File_Ref is an information given by the user while in process of printing the document, with the purpose of using such information later in search of the document as clue in finding the physical document. File_Location attribute of entity DOCUMENT stores the value of location of the physical document. Two other attributes of DOCUMENT entity are S_Date and File_Image, Date data type S_Date attribute stores the information such as printing date and time of the user accessing and printing the document. The last attribute File_Image is of Image data type and holds the image of the location, value stored in the attribute File_Location. The value of the File_Location will be driven on the basis of camera used for the document identification. The attribute value of File_Location and File_Image changes as change located in the location by the document identification.

The second entity CAMERA has two attributes. The attributes Camera_ID and Camera_Location both of numerical variable character data type. CAMERA entity is used to store the information of the camera used in document tracking process of HCW. Attribute Camera_ID stores the primary, unique value used for cameras in use. Camera_Location attribute stores the location of the camera depends upon the camera's permanent designated location. Depends upon the camera used, its Camera_Location attribute value will be used as value of DOCUMENT entity attribute Document Location (File_Location).

The last entity REPRINT, stores the data of the document which are reprinted and have more than one copy of the document. REPRINT consists of attributes File_Count, File_Copy and File_Purpose. First two attributes are of integer data type, File_Count stores the total count of the document copies and File_Copy stores the number of particular copy of the document in the total number of document copies. File_Purpose is variable character data type and its purpose is to store user's purpose for reprinting the document.

Table 4.1 Entities of the first version of ERD

Entity	Description
DOCUMENT	The DOCUMENT entity holds the information and details of every documents printed through HCW.
CAMERA	The CAMERA entity holds the data about the cameras in use.
REPRINT	The entity holds the information about the document which has reprinted or printed more than ones.

Relationship

DOCUMENT entity has relationships with both entities CAMERA and REPRINT. The relationship between DOCUMENT and CAMERA is one to many, each records of DOCUMENT can connect to zero or more records of CAMERA but records of CAMERA must be connected with exactly one record of DOCUMENT entity.

The other relationship between DOCUMENT and REPRINT entity is, many to many. One record of DOCUMENT entity can connect zero to more than one record of REPRINT entity. However, record of REPRINT entity must be connected to at least one record of DOCUMENT entity. See Table 4.3 for further information about all relationship of the ERD.

Table 4.2 Attributes of entities of first version of ERD

Attribute Name	Entity	Data Type	Primary Key	Description
File_Path	DOCUMENT	Nvarchar(MAX)	No	Directory path of the file chosen to print
File_ID	DOCUMENT	Nvarchar(MAX)	Yes	Inner file content which has used in tag

				for document identification
File_Ref	DOCUMENT	Nvarchar(MAX)	No	User given Document information
S_Date	DOCUMENT	Date	No	Date of document printing
File_Location	DOCUMENT	Nvarchar(MAX)	No	Documents current location
File_Image	DOCUMENT	Image	No	Image of documents current location
File_Copy	REPRINT	int	Yes	Reprinted documents number in the stack
File_Count	REPRINT	int	No	Reprinted documents total count
File_Purpose	REPRINT	Nvarchar(MAX)	No	Purpose of reprinting of the document
Camera_ID	CAMERA	Int	Yes	It's a unique ID given to

				each camera used in HCW
Camera_Location	CAMERA	Nvarchar(100)	No	This identifies the location of the camera

Table 4.3 Relationship between entities of the first version of ERD of the system

Relationship Name	Between Entities	Type	Description
Is Clicked	DOCUMENT / CAMERA	1:N	Must belong to exactly one CAMERA entity record
Has	DOCUMENT / REPRINT	M:N	DOCUMENT may have no record with REPRINT record but each REPRINT entity record must be in relationship of one or more than one DOCUMENT records.

4.2.2 Second Version of ERD

In the first version of ERD there was a many to many relationship between DOCUMENT and REPRINT entity. In contrast to the first version of the ERD, the second ERD consists of two instead of three entities. In the second version of the ERD (see Figure 4.3), there is only the DOCUMENT and the CAMERA entities, combining the attributes of the REPRINT entity into the DOCUMENT entity.

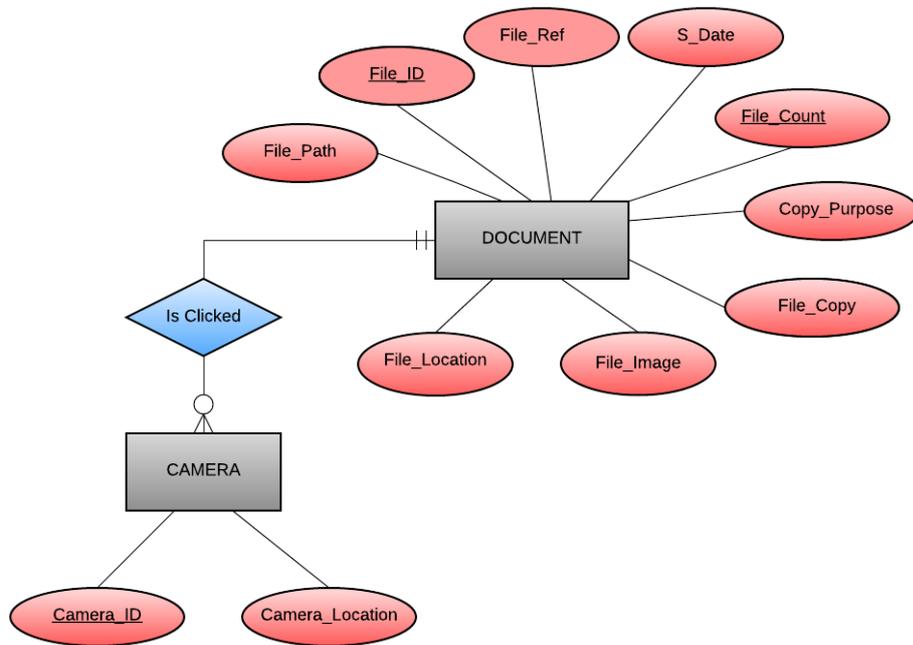


Figure 4.4 The second version ERD of HCW

Entities and Attributes

The changes made in attributes of DOCUMENT entities are further described with Table 4.4.

Table 4.4 attributes of entities of second version of ERD

Attribute Name	Entity	Data Type	Primary Key	Description
File_Copy	DOCUMENT	int	Yes	Reprinted documents number in the stack
File_Count	DOCUMENT	int	No	Reprinted documents total count

File_Purpose	DOCUMENT	Nvarchar(MAX)	No	Purpose of reprinting of the document
--------------	----------	---------------	----	---------------------------------------

Relationship

The relation between DOCUMENT and CAMERA entity is one to many and is termed as ‘is clicked’. The details of this entity relationship are given in Table 4.5.

Table 4.5 Relationship between entities of the second version of ERD of the system

Relationship Name	Between Entities	Type	Description
Is Clicked	DOCUMENT / CAMERA	1:N	CAMERA can belong to one or many records in DOCUMENT but DOCUMENT must belong to at least one record from CAMERA entity.

4.4 Overview of the Prototype Interface

As mentioned in Section 3.3, HCW has three basic steps that the user interface should include 1) Document Manager 2) Document Tracker 3) Document Search. After the document printing, the user will be allowed to keep his document in the workplace. If the document is already printed then system (Document Tracker) will give a location of the document. User interface module (Document Search) allows users to perform a keyword search and other option on search of a paper document.

As a result of the main three steps of HCW, the user interface has 7 different window forms that the user interact with. Each form has a particular function of our system. For example there is a page where user adds valuable information regarding the document they are printing, this information will later can be a key clue in finding the document. In addition to window form, there are multiple message boxes, input boxes which gives user an appropriate instruction, information about the user’s interaction with the function such as reprinting the document. For example, before

reprinting the document user will be informed if the document is already printed. System warns the user that reprinting will create another copy of the already printed document and system also provides the information about the document earlier printed. The document information such as documents current location helps user find the earlier printed document avoiding reprinting the document.

Figure 4.5 presents the structure of forms and message boxes. The pages are coloured red, whereas message boxes are coloured orange. Order number identifies the window form in this figure, while alphabetical characters identifies the message boxes. Figure 4.5 shows the relation between all forms and message boxes. The arrow show the transmission between pages and message boxes.

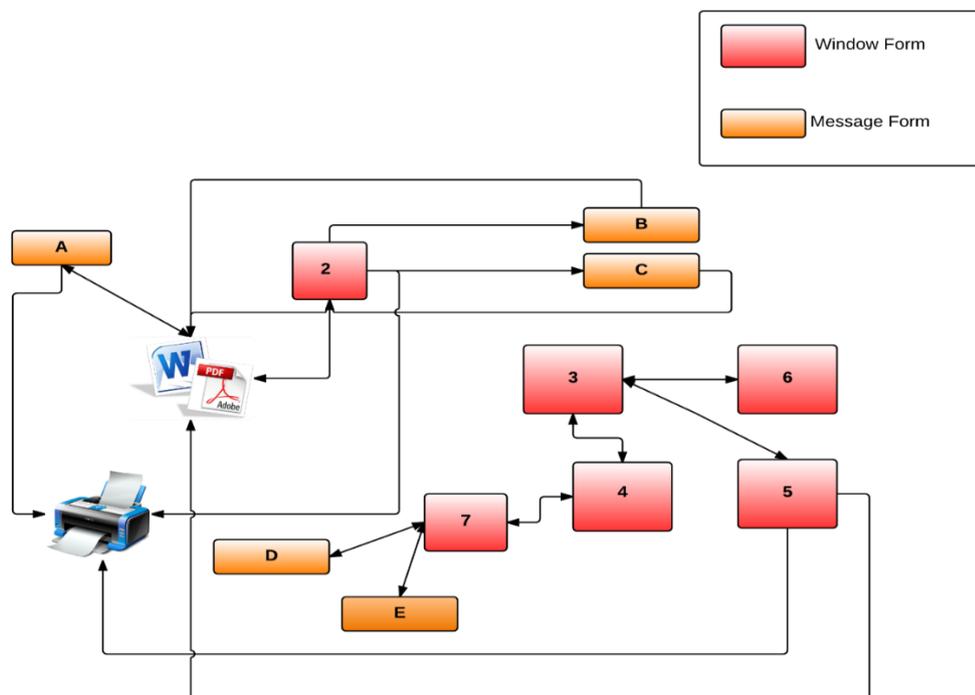


Figure 4.5 Overview prototype of HCW

Application (document viewer) page is connected to the window form 2: The Document Information which has a Message Box B and Message Box E and Window Form 2 connects to Printer. Message Box A is in relation to Printer. Window Form 3: HCW user interface is connected to Window Form 4: Camera Control Window Form 5: Document Search and Window Form 6: Application Exit.

In addition to Windows Form 6: Document Search is connected to the Application: Document Viewer and to Printer. Windows Form 4 moves controls to

Windows Form 7: Camera On/Off which has two Message Boxes, Message Box C and Message Box D.

Overview prototype of HCW does not provide many details on the function that window form and message boxes have or it does not describes the reason or purpose of each message box. However, it presents the picture of overview connection between window forms and message boxes.

4.5 HCW User Interface

We will use the persona of scenario in Section 3.2 to present the user interface from the user's point of view. User like Helen is supported by the HCW system to manage, organize and to find the document. Section unfolds the user's interaction with HCW using the scenario.

The persona of the scenario, Helen is in her office at the university and is currently working on the conference papers and in the process of using several papers for reference. She will now use HCW to manage her documents.

Attempt of printing document

Helen finds a document that she wish to print for detailed reading and note marking. She selects the print option on her document reader and gives the print command (see Figure 4.6).

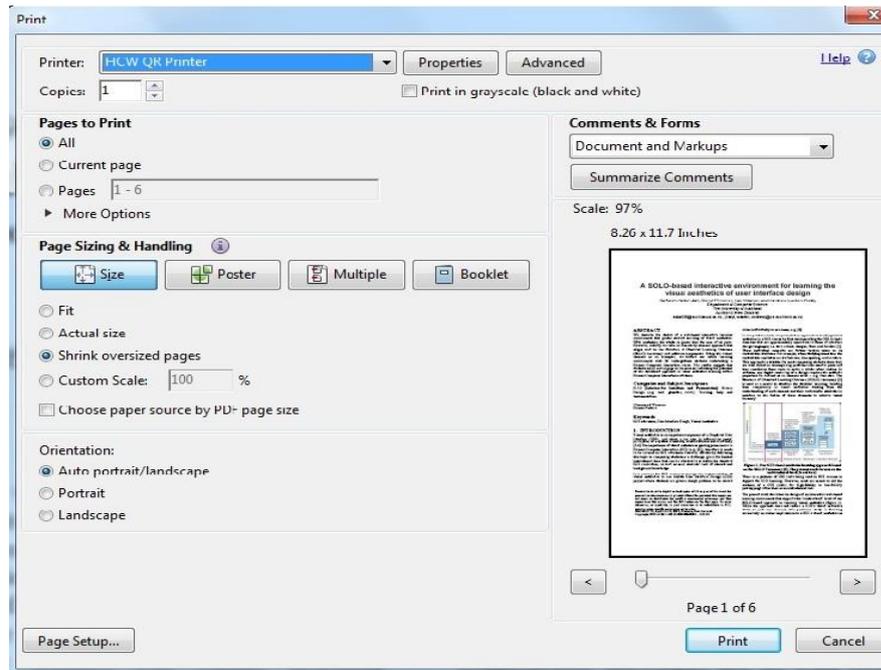


Figure 4.6 Screenshot Document printing window form

In the background HCW performs a Document Duplication Check looking for the pre-existence of the document in the system. After Document duplication returns negative, Helen is asked to input the information about the document (see Figure 4.7). She writes 'In reference for JCDL' while printing in progress she continues her document search until a window pops up stating the document is ready to be collected. Helen collects her document from the printer.

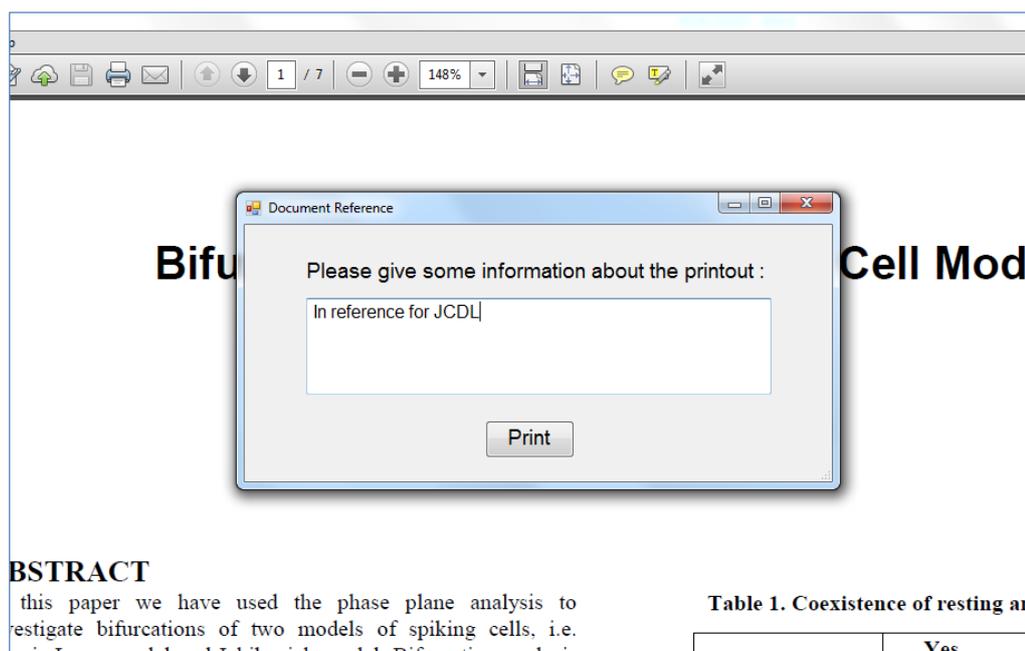


Figure 4.7 Screenshot of Document Reference window

The Front page of the document with 2 D tag helps Helen verify the document. She takes the document to her desk, works on it and then places it on her desk for reading later.

Attempt to reprint the document

Unable to locate her document later and needing a copy Helen decides to reprint. Using the print command returns a window showing a positive document duplication check, the print date, the information given while printing and the document's current location. Now Helen knows her document is on her desk but considering her desk size it would be difficult to find the document. Helen clicks on the location field and gets the visual assistance of the location.

She went back to her research work and continue to read abstract of other papers, she felt the paper title 'Prioritized Energy' does have points she were missing and she should have this document for reference, for marking. She gives command to print the document, in return the message window pop up stating the existence of the document (see Figure 4.8). The window returns the document information such as date of print, current location of the document.

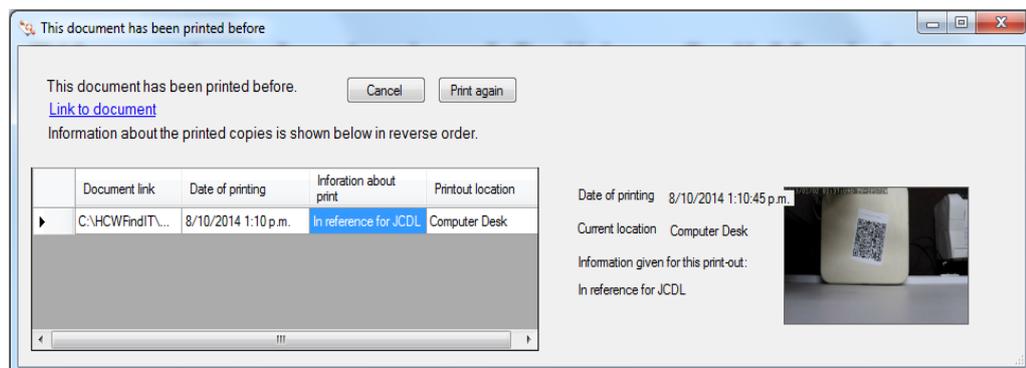


Figure 4.8 Document Duplication Window

The document is on her desk. The image of the location provided along the information narrows the document location area to the computer's right side of the desk. At that time she reads the document information which she provided at the time of document print, the information reads 'In reference for JCDL'. The document information is the cue that recalls her memory of the events occurred and steps she taken after printing the document. Thanks to the information clue, now she knows this document is in pile of other JCDL documents making her retrieval easy and

quick. The re-printing of the document was possible but Helen does not see the reason of her to re-print the document.

It is a busy morning for Helen, it is well past her lunch time and she has not had her lunch yet. Over the years she have gathered many documents and today she find one from her old documents that she is seeking to read again. Before going for lunch, she wants to take a copy of the document with her to read.

She gives print command, system informs Helen that there are two copies of the document (see Figure 4.9). She click on the record of both documents one by one, the first document is on the round table next to her so she quickly reaches to the table and without any difficulty finds the copy.

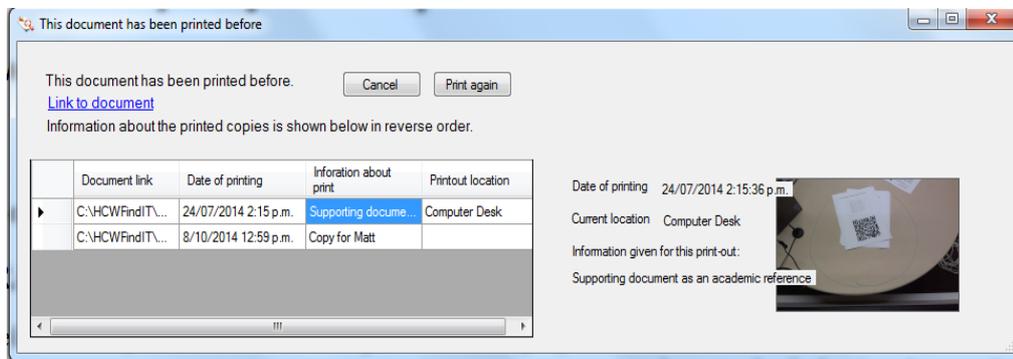


Figure 4.9 Second Copy of the document

On look for second copy she finds the ‘Current Location’ field empty so she looks for information about print. The information reads as ‘Copy for Matt’, reminding her that she printed that copy for Matthew Axelson for him to have the copy with him in his office so that means the copy is not in her office. Now without further search, she grabs the found first copy and makes her way for lunch.

Attempt to search physical document

Helen stumbled upon the document titled ‘Cell Models’, she feels she has the copy of document and she has taken her notes on the copy. She activates the user interface of HCW, clicks on the HCW icon on her desktop. From the given three options she selects ‘Document Search’.

Document search window gives her option of searching the document by dates or by keywords (see Figure 4.10). She put the keyword in the field. Her keyword search return three results in the result window. Result reflects that she has maximum two

copies of the document. One by one she click on both document listings. As she click on the document she is seeking, document details such as image of location, document information appears in one corner of the window. Both the documents are on her square shaped laptop desk next to the printer. Helen compares document information of both copies in response to reach out for the accurate copy from the available two copies. After checking and comparison of both document printouts information she knows that it's the second copy from two that she is after.

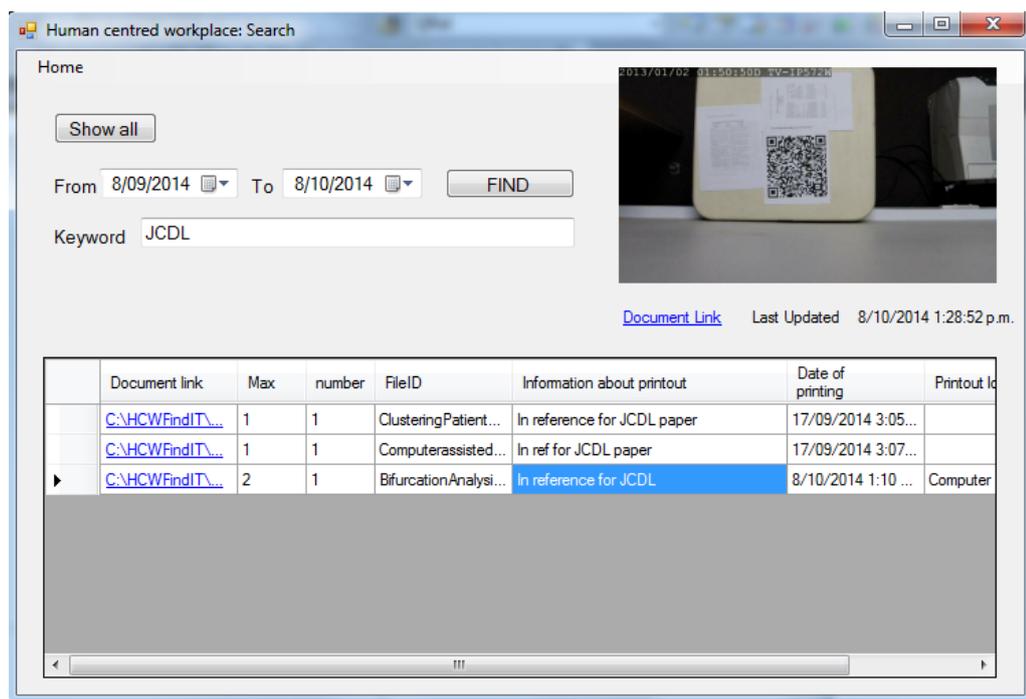


Figure 4.10 Document Search by Keyword

One more time she takes a glimpse of the document's location images and heads over for collecting the document.

4.6 Summary

This chapter has presented the implementation of a prototype to manage, organize and to find the physical documents in a workplace.

At beginning of this chapter, we presents the technologies that we propose to use to implement HCW. Our system's conceptual architecture is designed considering the technologies full filling our requirements. Section 4.2 describes the deployment process of HCW. The implemented system HCW consist of three components that

co-operate with each other. Human-Centred Workplace is a .net GUI application that enables users to create, print and locate the physical documents. HCW system interacts with the other tools such as printer and cameras for document printing and for tracking the document respectively. The Document Manager component of HCW system is implemented in .net composed framework and keeps a record of the documents user prints. The cameras are used in the Document Tracking component which is developed in the .net framework and completes the tasks such as tracking document and passing the information back to the Document manager.

Section 4.3 presents the database used for the HCW. As the database local storage was preferred, consequently a light database was designed and established in order to install the database on the user machine. To construct a strong database and a relationship between the tables, the entity relationship (ER) diagram was drawn. The ER diagram provided a visual representation of the design, it was crucial information for the effective database design. Further, ER diagram emphasis and delivers understanding of communication which helps in high flexibility of the system database. In Section 4.4, the overview of the user interface gives us good understanding of windows forms and user relation. In Section 4.5, a scenario was used to clearly explain the interaction between the user and the system.

We conclude this chapter with user given in-depth interaction with the system interface. This chapter of implementation and user interface establishes the platform for next chapter, system evaluation. The next chapter will evaluate the usability of HCW with user studies.

5 Evaluation

This chapter reports our evaluation of the completed system prototype in respect to the requirements specified in Chapter 2, and determines if our prototype satisfies the goals specified in the thesis problem definition in Chapter 1. Furthermore the system prototype will be evaluated with a group of end users on the basis of tasks.

As the HCW system is interactive in nature, technical evaluation and performance measures alone (such as speed), while important, and are not sufficient for evaluating the system prototype. Therefore, we conducted user studies to evaluate the system *in action*. The goal of these studies was to confirm the feasibility and convenience of using the tool and to highlight points of failure that need to be addressed in future implementations.

We ran two studies. The first user study evaluated a single user's interaction with the system over a two-week period in the user's own office (Section 5.1). A second user study deployed the system in the usability lab there it was used and tested (for 15 – 20 minutes) by a number of study participants (Section 5.2). Insights from both studies are discussed in Section 5.3.

5.1 Office-based user study (single user over 2 weeks)

We first describe the setup of the study (Section 5.1.1), then the participant (Section 5.1.2) and then the results of the study (Section 5.1.3).

5.1.1 Study Setup and methodology

We set up the prototype system in one computer scientist's office (see the layout in Figure 5.1). The system was run on a Dell OptiPlex 9020 with Intel® core™ i7-4770 CPU 3.40 GHz processor and 16 GB memory. The setup used two cameras with different resolutions, frame rate and image quality: (1) one high-resolution USB 2.0 camera and (2) one network camera. The first camera produce mega pixel 1600 x 1200, colour images at 25 frames per second, and the second one, a mega pixel resolution up to 1280 x 800 wireless and Internet camera, produces images at 30 frames per second and mega pixel resolution up to 1280 x 800. The initial camera was mounted 100 cm above the desk with the tracked area approximately 30 x 40

inches (76 x 101cm). The second camera was mounted 125 cm above the desk used by the participant for keeping papers.

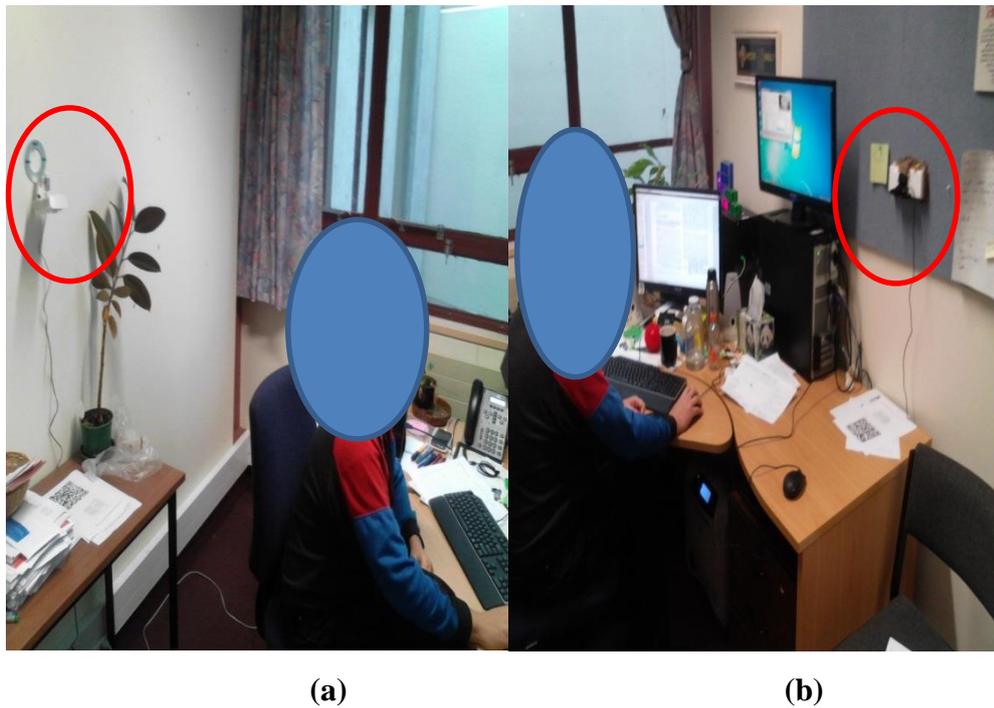


Figure 5.1 System set-up in anonymised participant's office, cameras in red circles (camera 1 (a), camera 2 (b)).

The system was deployed in the participant's office for a period of two weeks and during that time, the participant used the system on a regular basis. We collected qualitative data from the experience of the participant while using the system: the participant kept a diary to record any incidents, events and interactions. These included events of failure, success, system flaws, and general behaviour of the system that affected the user's routine work practice. In addition, two interviews were held with the participant: the initial at the end of the first week and the second interview at the end of the two weeks of the user study. The interviews with the participant were aimed at obtaining a deeper understanding of the participant's experiences and concerns about the system. The researcher took notes during the interviews.

5.1.2 Participant

The participant was a computer scientist recruited from the Computer Science Department at the University of Waikato. Before the participant used the system on their own, they were shown a system demonstration. This participant will be referred to as OP1 in our discussions.

5.1.3 Results

OP1 divided the system evaluation into two phases, printing document phase and searching the physical document phase. The participant was asked to note some general comments about the system.

Printing phase

In the printing document phase, OP1 noted that the system failed to print some of the pages of the documents. OP1 performed the printing task a number of times and on each occasion only the first four pages of the documents printed successfully. OP1 noted ‘Little disappointed, got merely four pages printed out of the 18 page document’. When asked whether the about was the printing time consuming. OP1 expressed, the process was a little bit time consuming. However OP1 expressed satisfaction with the front page of the document, stating it provides sufficient information to identify the document, the page content has structured well and easy to differentiate from other documents’.

Search phase

A computer scientist by profession, OP1 goes through the same document a number of times for referencing purpose. If the document is not visible on the desk OP1 finds, that it easy to reprint it. OP1 found the document duplication catch a useful feature to prevent reprinting the same document noting that the document location information given to the document duplication check helps find document.

OP1 praised the simplicity of user interface for finding a physical document, stating that ‘It was an easy to understand and simple to interact user interface’. Further OP1 notes that the availability of different searching parameters such as keyword search and between-two-dates search makes the search more accurate and targeted. OP1 notes “Document search was successful, but images show two documents at one place, do not know which one is mine”, expressing difficulty in distinguishing between two documents shown in image. However OP1 suggests that highlighting the user required physical document in the images will provide a solution to distinguish between two documents in image.

General comments

Although user OP1 in this study found problems with some aspects of the system, the participant felt that these did not hinder his ability to use the system successfully to manage his research-related document management. Most of the problems were implementation specific which could be avoided in future versions. Although the system “crashed” several times throughout the study period, the document were recovered through a recovery mechanism. Overall, OP1 found the use of software “convenient” and said that “the software makes sense.” OP1 found the software “useful” and thought that’s what helps in organizing document in the workplace.

5.1.4 Changes to the system after first study

First study as follows:

- The problem of the system was not printing all the pages of the document, was traced to a malfunctioning print spooler service on the system. The error was addressed, and changes resulted in successful printing of the whole document.
- The occasional shrinking of the QR code, leading to a decoding failure was due to encoding more than 500 alpha – numeric characters in the QR code. The error was addressed by a changing in the error correction parameter from a high level to a low level. As the higher the error correction level, the lower the storage capacity of the QR code. By default, the QR code applies a high level of error correction, affecting the storage capacity and making the QR code bits shrink in size.

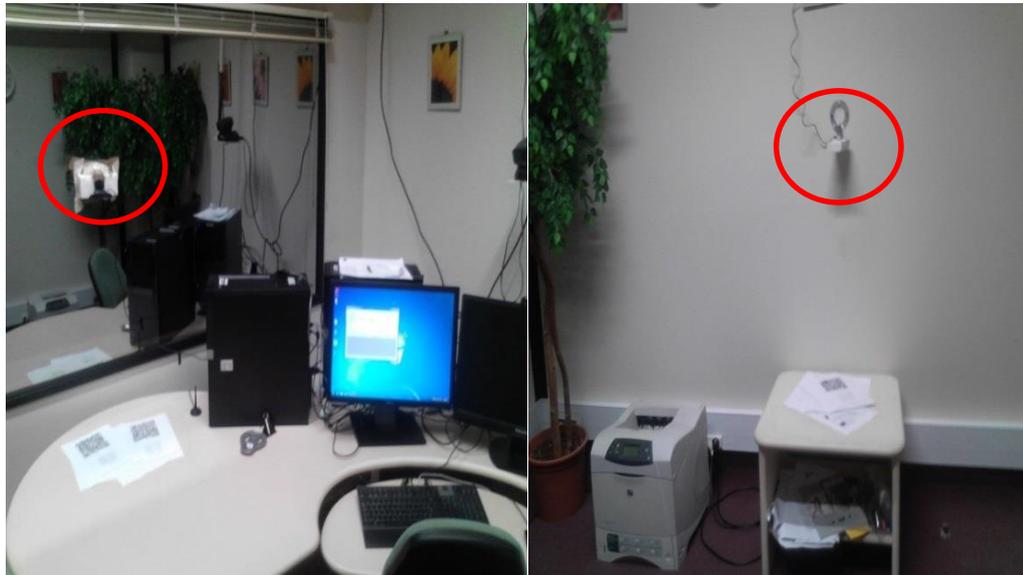
5.2 Usability-lab user study

As in user study 1, we first describe the setup of the study (Section 5.2.1), then the participants (Section 5.2.2) and then the results of the study (Section 5.2.3).

5.2.1 Setup and methodology

We used the modified prototype, and the same cameras as in the first study. The first camera was mounted 100 cm above the desk. The tracked area of the desk was approximately 30 x 40 inches (76 x 101 cm). The second camera with resolution

1280 x 600 was mounted 125 cm above the desk used by the participants. The setup is shown in Figure 5.2.



(a)

(b)

Figure 5.2 System set-up in the Usability lab (camera 1 (a), camera 2 (b)).

The usability-lab user study was designed to be task based, followed by questions and user feedback (the material is attached in Appendix A). At the start of the study, each participant was given a short introduction to the study, their rights as a research participant explained, and asked to sign the Informed Consent form.

Each user was given an introductory questions to answer. These questions allowed us to understand how frequently a user searched for the printed document, the technique the user used to find documents and whether the user re-prints documents when they cannot find them.

For the user study, each user was given a task sheet and asked to perform three different tasks: (1) print the first copy of the document, (2) print a second copy of the document and (3) find the location of the document (see Figure 5.3). After performing each task and before continuing to the next task, users were asked to answer questions based on the task.

TASK 1: PRINTING FIRST COPY

Please select one of the document samples and print the document such that it can be tracked for its physical location.

- Successful printing
 - Yes
 - No

- How difficult was the printing such that the document can be tracked?
 - Very Easy
 - Easy
 - Normal
 - Difficult
 - Very Difficult

- Was the process time consuming
 - Yes
 - No
 - Chance of improvement – please specify

- Is the information available about the document printout (first page) sufficient to identify the document?
 - Yes
 - No
 - Chance of improvement – please specify

TASK 2: PRINTING SECOND COPY

Now place the document from task 1 somewhere in your workplace (in the usability lab) Please print another copy of this document to give to someone else.

- Successful printing
 - Yes
 - No

- How difficult was the printing of a second copy?
 - Very Easy
 - Easy
 - Normal
 - Difficult
 - Very Difficult

- Was the process time consuming
 - Yes
 - No
 - Chance of improvement – please specify

- Is the information available about the document printout (first page) sufficient to identify the document?
 - Yes
 - No
 - Chance of improvement – please specify

TASK 3: FINDING A PHYSICAL DOCUMENT

Use the system to find the physical location of the first printed document.

- Successful finding
 - Yes
 - No

- How difficult was the finding of the physical copy?
 - Very Easy
 - Easy
 - Normal
 - Difficult
 - Very Difficult

- Was the process time consuming
 - Yes
 - No
 - Chance of improvement – please specify

- Is the information available from the system sufficient to find the document?
 - Yes
 - No
 - Chance of improvement – please specify

Figure 5.3 Task list

In Task 1, users were asked to select one of the document samples from the ‘Document’ folder containing documents present on the desktop of the user’s computer. After selecting the document, users were directed to print the document. The document was placed somewhere in the workplace (usability-lab). In Task 2, the user was asked to attempt to re-print the same document from the desktop. The task was performed to test the software’s ability to catch the attempt at re-printing the earlier printed document. In Task 3, the participant was asked to find the location of a physical document with the use of Human-Centred Workplace’s user search

interface. This search interface gives the user the option of performing a document search based on different parameters such as print date and keyword.

5.2.2 Participant Sample

This study involved 10 participants (6 female, 4 male) ranging in age from 18 to 50 years. We invited participants from a variety of backgrounds who familiar with computer use. In exception of one, all participants were university students. One participant was a technology field professional. Among 9 university student participants, 2 were postgraduates, while rest were undergraduates. The university student participants were from different study background (2 arts & social science, 4 management, 2 computer science and 1 from earth science).

From the initial introductory questions, we found that the participants had all often searched for documents that they had printed before, spending on average 2-3 hours on the document search. The participants are referred to by number, from UP1 (Usability-Lab participant) to UP10.

5.2.3 Results

The results is according to the tasks the participants executed and through the results of the evaluation of the feedback given by the users.

Background about document search

Task 1: Printing a document

While performing Task 1, all ten participants found printing the document with a QR code tag was relatively simple (see Figure 5.4).

Seven out of ten participates appreciated the concept of the request for additional information about the document, to help in finding the document, but noted they needed more help in understanding the purpose of the information request. Two out ten users felt the request for additional information about the document before they were able to print it delays the process and also that information supplied do not help them in locating the document location.

Printing Document

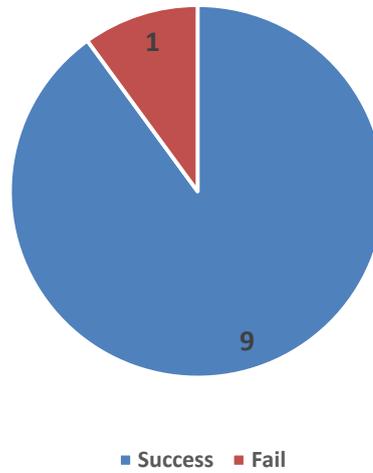


Figure 5.4 Printing document

Some participants identified particular problem they had encountered for example. UP2 attempted to enter special characters as an input in the text box of the information request, but this failed and the participant recorded their dislike of not being able to use special characters. Participants were also noted that they expected task window to appear as a pop up but was shown in task bar. For four out of ten participants document printing was less convenient (see Figure 5.5).

Printing convenience

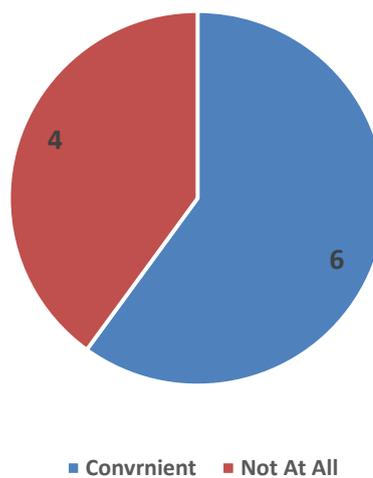


Figure 5.5 Participant feedback on document printing convenience

For Task 1, the same four out of our ten participants felt that the time the system took for the printing of the document was too long (see Figure 5.6).

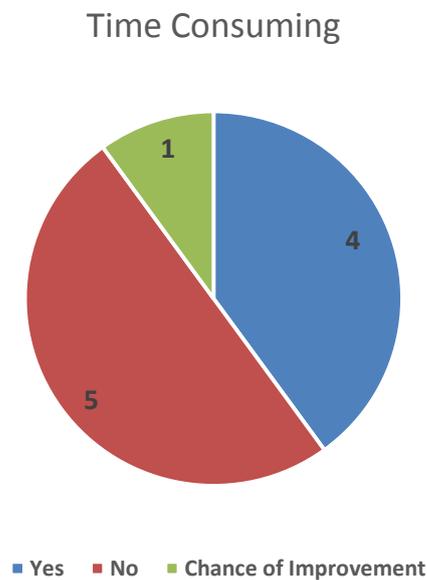


Figure 5.6 Printing time consuming

Further eight out of ten participants felt that the information provided on the front page of the document was sufficient to identify the document (see Figure 5.7).

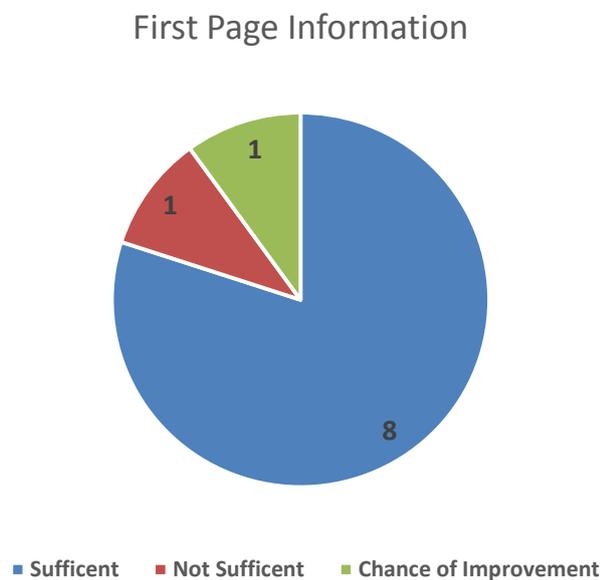


Figure 5.7 Participant feedback on first page information

In response to suggestion for task 1, UP 3 wrote, they would like to see the initial information request with a possible mouse over hint box to explain the purpose of

requesting information about the document. UP 8 and UP 9 suggest that having a progress bar to show the progress of document printing would be useful.

Task 2: Printing the second copy

In Task 2, printing the second copy, all ten participants noted that catching re-printing of the document and providing information about the document with its current location saved them from re-printing the same document (see Figure 5.8).

UP 5 wrote, that ‘Avoiding reprint of the document is a very useful feature, as it would help me to avoid having multiple copies of the same document in the office.’ UP 8 mentioned, ‘In further to avoid document duplication, the system provides details of a number of document copies printed, encouraging using the existing copies than printing new copy.’

Document Duplication Check

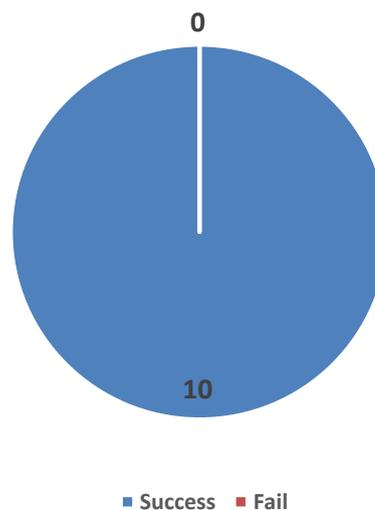


Figure 5.8 Document duplication catch task

All ten participants noted that document duplication was successfully caught. Further, out of 10 only one participant went to reprint the document, another 9 successfully found the document from the workplace with the help of the document information; images of the document's location provided with the document duplication catch window. When asked about the time taken by the process, five out of ten participants felt that the process was not time-consuming (see Figure 5.9).

Time Consuming

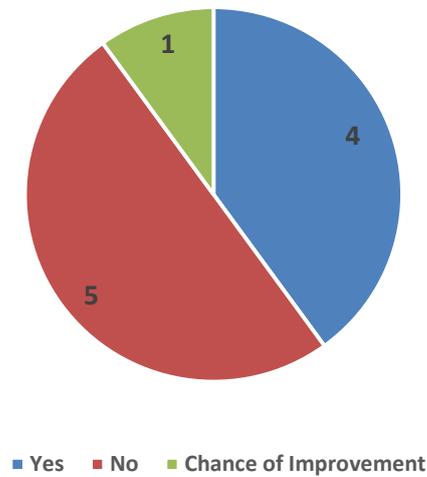


Figure 5.9 Participant feedback on time taken for task

As a suggestion for task 2, UP4 mentioned if the user decides to re-print the document, the reprinted document's information on the front page is same as in the first document. UP4 suggested providing document printout number and date of reprinting, will be useful to differentiate the physical copies of the same documents. UP 8 suggested "Would like to see more info of the document."

In another suggestion UP 6 suggested, after reprinting the document, auto closing the document duplication catch 'This document has been printed before' window will be more useful.

Task 3: finding a physical document

In Task 3, participants were asked to use the interface search window to find physical documents placed in the workplace. Seven out of the ten participants were successful in finding the physical document however three failed to find all the documents they were seeking. They reported the physical document finding as unsuccessful (see Figure 5.10).

Finding The Document

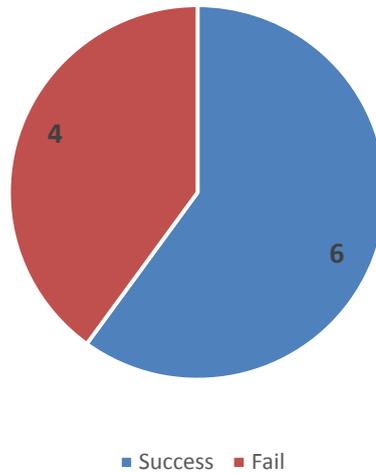


Figure 5.10 Participant finding the document

Eight out of ten participant reported that the process was effective and was not time consuming (see Figure 5.11). Three had difficulty using the search window efficiently and needed to ask the researcher for help; these users suggested that the user interface layout should be more informative. On two occasions, UP 9 observed clicking on a document whose location has not been updated resulted in the system failing to refresh the documents location image window.

Time Consuming

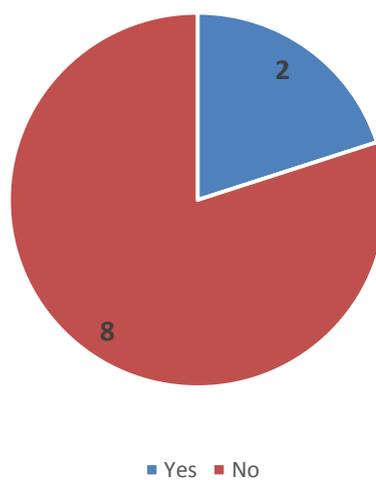


Figure 5.11 Participant on document searching time

UP3 suggested there should be a function to check the functionality of every camera placed in the workplace. If the camera at the particular location not functioning then the problem could be fixed by indicating the status of the camera on the task bar.

General comments

All ten participants stated they were excited about the idea of automatically keeping track of their desk papers. Five out of the ten participants found the system convenient noting that it was as very useful (see Figure 5.12). As UP1 wrote “The system is amazing; it will help to keep track of each and every document” and noted that the, system made it easier to find papers on the desk, simply by showing the picture of the desk the paper is on.’ UP 9 wrote that ‘This system is convenient and useful for a forgetful person like myself. Not only does it helps to find printed document or where my file is, it also helps the environment by avoiding re-printing.’

UP 8 wrote, that the ‘System is very useful as I could see which documents have been printed earlier. Also, I can track the document’s location.’ UP 8 suggested that a progress bar could be indicated in the system to show the progress of document printing.

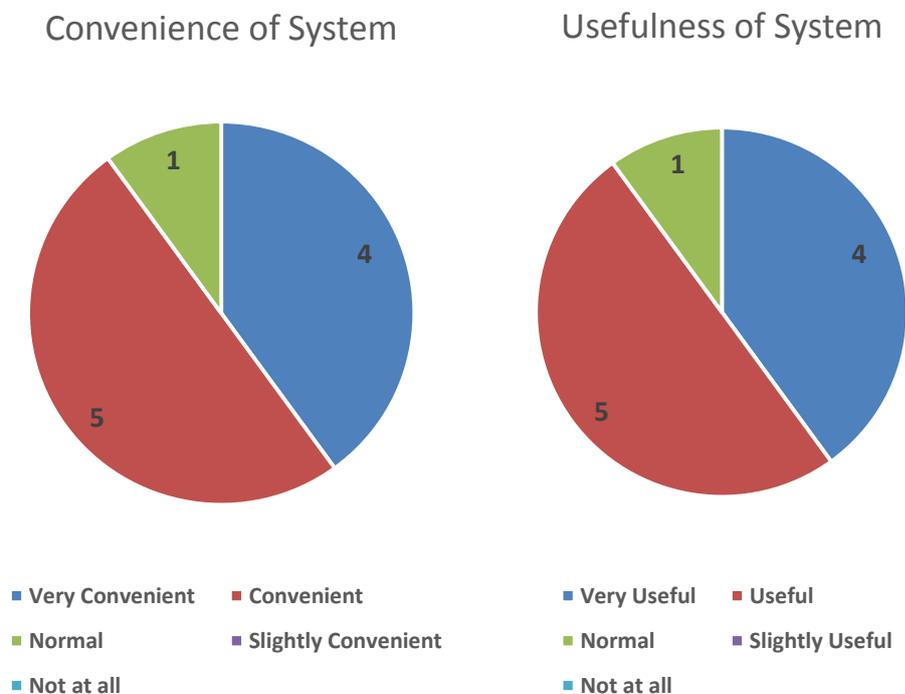


Figure 5.12 General feedback results

5.3 Discussion of the two studies

This section will discuss participant users' feedback from both the office-based and the usability-lab study. It will also cover technical problems encountered during both studies.

5.3.1 Comment on participant observations

Participant background.

The background of the participant seemed to affect the way they approached and interacted with the system. As already noted, we aimed to have participants from different backgrounds, other than computer science to take part in the user study. We observed that users from backgrounds other than computer science focused more on the outcome of the system as underlined by one of the user feedback, 'It is very cool, will be of great help to organize and search the physical documents.'

On the other hand, the participants from computer science background seemed to be more critical of the operational aspect of the system. They seemed to find it harder to accommodate even a small system delay. It is observed computer science participants were more analytical of the systems performance. Participant from other backgrounds on an average took 20 minutes to complete the user study; on an average computer science background participant took 30 minutes.

Participant interaction and response

The user evaluation study showed that users appreciated the benefits of tracking paper noting that they could use the system whenever they needed to without no special effort. It clearly saved their time searching for the document.

5.3.2 Technical challenges

Speed of processing

Participants felt that the system would benefit from having a faster response time because of the delay in processing each frame. As the user had to pause between adding papers to the desk. Currently, the system takes about 2-3 seconds to recognize the QR code. Improving the efficiency of the recognition method would solve this

problem. We anticipate that a frame processing time of one second or less would be appropriate for this task.

Reading QR at an angle

The problem of the code not been read accurately was traced to camera angle. One of two cameras was faced on an angle to the desk and the other was perpendicular to the desk and ultimately to the document. In comparison to the encoding QR code from an angle, encoding QR code in straight level facing the document; shown higher success in reading. We therefore conducted an experiment to investigate the issue future as every time placing camera perpendicular to the document would not be possible.

5.4 Follow-up experiments

The camera mounted 110 cm above the paper on the desk. The size of the QR code on the paper was chosen to be 10 – 10 cm in dimension. To experiment with the QR code decoding at an angle, we changed the camera angle facing the desk from 0° to 45°. The results of the experiment are shown in Table 5.1

Table 5.1 Reading QR code from at an angle, experiment 1

Sr No	At an angle	Reading was successful					Average
		1	2	3	4	5	
1	0	✓	✓	✓	✓	✓	5/5
2	10		✓	✓	✓	✓	4/5
3	20		✓		✓	✓	3/5
4	30				✓		1/5
5	45						0/5

Table 5.1 shows the number of successful attempts to read the QR code at a distance of 110 cm from an angle range of 0° to 45°. In the experiment the size of QR code was fixed to 15 x 15 and the camera used was the same as used in the user study (Section 5.3). Table 5.1 shows the average of the success ratio of the different angle

of the camera facing the document. The QR code reading rate for the camera at 0° facing the document where 100% as all five attempts were successful. A change was noticed with a 10° to 20° change to the camera angle. The reading ratio for the QR code at the camera at angle 30° facing the document where 40%, two out of five attempts were successful. The ratio went further down to 10% for reading the QR code when the camera angle was changed to 40° facing the document and failed to read the QR code event one time from the camera angle 45° in the document.

To extend the experiment we decided to increase the distance to 125 cm above the desk. Similar to the first experiment of reading QR code at an angle the camera angle was changed from 0° to 45°. The results of the experiment are shown in Table 5.2. Similar to the earlier experiment, the size of QR code was fixed to 15 x 15, and the camera used was the same as used in the earlier experiment.

Table 5.2 Reading QR code from at an angle, experiment 2

Sr No	At an angle	Reading was successful					Average
		1	2	3	4	5	
1	0	✓	✓	✓	✓	✓	5/5
2	10	✓		✓	✓	✓	4/5
3	20	✓			✓		2/5
4	30					✓	1/5
5	45						0/5

Similar to the previous experiment, in this experiment camera at an angle 0° to 20° shows the success in reading QR code. The results for camera at angle 30° to 45° are identical to the results of experiment one (shown in Table 5.1). Hence, from this finding we conclude reading of QR code at an angle 30° to 45° fails. Further, increasing the distance did not reflect on the results but the experiment underlines the failure of reading QR code at an angle.

Overall

As the accuracy of the document tracking is critical for providing consistent information to the user, this is an important issue. From the experiment, we observed best possibility for an accurate QR code reading when cameras are at an angle from 0° to 20° facing the document. We note, in success of reading QR code it appears that the height is not as critical as reading QR code from an angle.

5.5 Summary

This chapter reported on the results of our evaluation of the system prototype as described in this thesis. The user study evaluation shows how the different requirements of the HCW system have been fulfilled. Two user studies were conducted to test the feasibility, convenience of the HCW system.

The first study, involved with one participant using the system for a period of two weeks. Over this time the user made feedback notes and those feedbacks was used to make changes in the system before conducting second user study.

The second study, involved participants who were asked to perform three tasks 1) Printing the document 2) Reprinting the document and 3) Document search and evaluate each steps on a scale of difficulty. On average the user took 20 – 25 minutes to perform all three tasks. The feedback revealed some technical challenges occurred during the studies, to understand and find possible solution for the challenges we conducted two experimental studies.

The user studies were focused on testing convenience and feasibility of HCW system. Participants found the system convenient to use and they reported that they appreciated the benefits of tracking papers. Participants particularly expressed satisfaction with functionalities such as the Document Duplication Check. All participants reported finding the system very useful. During the study, we identified some technical challenges, such as processing time for the QR code causing delay. In the future implementations, improving the time taken for capturing images and recognizing papers should be addressed. Another challenge for the HCW system was that reading the QR code from an angle was problematic. We conducted further investigations of reading the QR codes at angle with two cameras at angles between

0° - 45° (discussed in Section 5.4). We found that the success of reading QR code with an angle 0° - 20° depends upon the camera.

The next chapter summarise the thesis and recommend methods that could improve the user interface as well as adding new features to HCW from suggestion made in the user studies.

6. Conclusion

This concluding chapter summarizes the research presented in this thesis and also outlines the steps that were undertaken to reach the objectives of the research. We discuss the limitations of our current prototype and, in the final section, present ideas for future work suggestions.

6.1 Summary of the thesis

This research set out to propose a new solution for addressing a user's need to find physical documents and to design a system that supports the managing and finding of physical documents. Our approach to the problem of managing and finding physical documents is called the Human-Centred Workplace. The Human-Centred Workplace (HCW) is a system designed to keep track of the physical documents and so users can locate them easily.

Chapter 1 describes the existing problems in finding and managing physical documents. Reference is made to number of studies done with knowledge workers, which show that people can waste a considerable amount of work time finding physical documents. The current situation in physical document finding was described in terms of the issues and its consequence for users. Five requirements of the system Human-Centred Workplace; 1) keeping a record of a printed document, 2) keep track of the location of the physical document, 3) digital search facilities, 4) not to be a need of user to follow any specific order, and 5) minimal hardware requirements are defined in Chapter 2. Further Chapter 2 is based on our consideration of the problems with physical documents outlined in Chapter 1.

The conceptual design of HCW was presented in Chapter 3, with the idea of using QR code as a document identification tag in HCW. We introduced a scenario to illustrate the conceptual design. HCW system design includes three steps; printing a document, tracking the document and searching for the document.

Chapter 4 begins with the presentation of technologies used in the implementation of HCW followed by the system deployment. It then addresses the design of the database with the use of an entity relationship diagram (ERD). The system

implementation was presented through a user scenario. The final prototype is fully functional and is described with its task orientation.

Our HCW prototype tracks the document with the use of cameras placed in the workplace. Each time the document is tracked and located by the system, its location is automatically updated in the database. Through the interface user can perform a document search locating its physical location. This makes the workplace more user-centred providing the required documents in quick succession.

From the user studies it has become clear that keeping a record of printed documents helps users manage their documents and prevent reprinting. In the user study, participants seemed comfortable finding physical documents when provided with memory-triggering document information by our system. The participation of users from different background was helpful for the analysis of the system. The user evaluation study showed that users appreciated the system.

6.2 Limitations

Our current system prototype has been developed and evaluated predominantly with research paper documents. There were two reasons of choosing research papers as the document for this prototype. Firstly, we needed to evaluate the system in a real implementation setup where users would be handling many documents. Researchers experience the difficulty in keeping up with their location. Secondly, a research paper has a fixed structure, which makes it easy to work on initial stage of the prototype. While we test Human-centred Workplace in this specific domain of document type, we propose that the system will perform accurately on other document types as well.

The use of QR code also has introduced some limitations. Our experiment reported in Section 5.4 shows that the QR code tag cannot be decoded at above a certain height. Further issues have been observed when using a wider angle for scanning the QR code. These two limitations restrict the systems area in which it can reliably perform document tracking. We will address a possible alternative in our future work section.

6.3 Future Work

This section discusses possible future improvements in the current 'Human-Centred Workplace' prototype. These proposed changes in the current system are expected to make the system more user-oriented and to make information extraction more accurate and faster.

6.3.1 Document Pile Tracking

Difficulty: As has been demonstrated it is difficult to classify the document in a pile of documents. The current system did not provide the function of tracking the document from a pile, a possible extension would be 'Pile Tracker'.

Aim: Once the piles are formed, user should be given functionality to track the document from the pile. Further keep an order of the document in the pile for an accurate and quick document retrieval.

Proposal: On every document addition to the workplace depending upon the documents placing the new pile will be created or an existing pile record will be updated with new document. Every piles will have an information such as its location and the order of document it contains.

We suggest possible ways to implement pile tracking.

Creating a pile / adding document to pile: When a new printed document is recognized in HCW but cannot be found in the workplace, then it should be assumed that paper has been placed in an empty space or on the top of another object. This occurs when no overlaps with other documents are detected. These give us a new pile. If the document is overlapping with other document then it should be considered as on the top of an existing pile and the new document will be added to the respective pile.

If a document is moved or removed from pile: This could be detected when an existing document moves over the desk surface. If a single document is moved; the document is detected when its pile contains other papers. If the pile has only one paper then it will be processed as a whole pile moved. If more than one paper is moved then it will need to understand whether whole pile is moved or the pile was

split. If any other document in the pile becomes visible then it's a split. Otherwise we assume the whole pile is moved.

If a paper is removed: A paper is removed from the desk if the paper below it becomes visible and the paper itself has not been read by the system.

Pile List View

For users to detect the document from pile, we propose a pile list view which will be displayed. Each pile list view will present a list of documents with an image area showing the pile of documents. A pile list view will have two levels, the top document level and second one for a document below. The image system highlights the top documents. We propose to use a different colour for every pile.

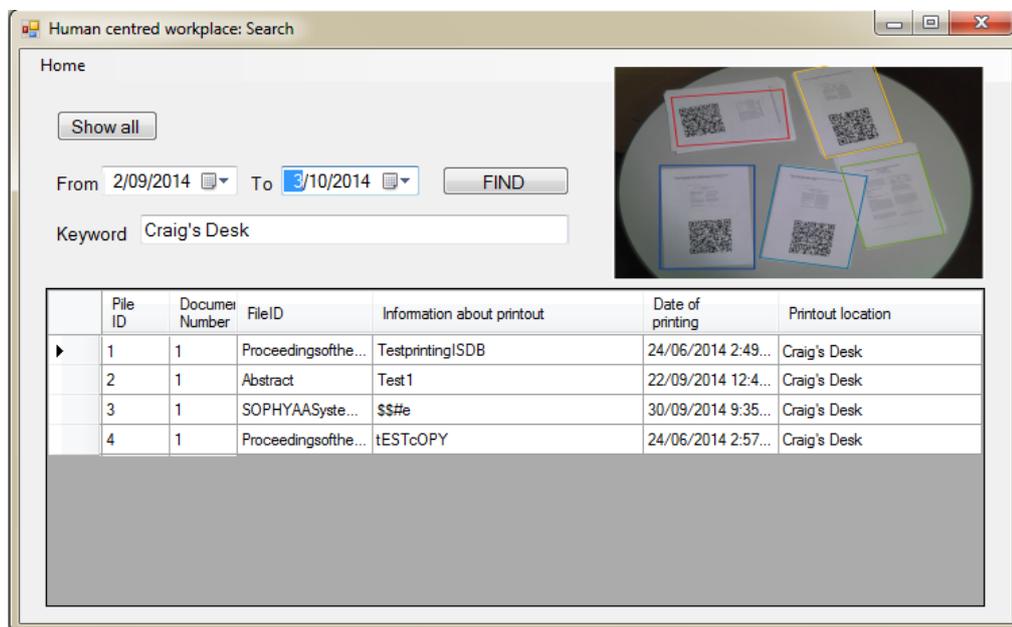


Figure 6.1 Pile tracker mock-up

Figure 6.1 is a mock-up of the proposed Pile tracking user interface, giving user a list of the document in a pile with image of the user desk highlighting each pile with different colour.

6.3.2 Improvements in the User Interface

We developed the first version of the user interface of HCW through which user manage their physical documents. Further versions could address further user needs. The new user interface should make system easier to interact with and more effective in information retrieval. The user interface can be extended in several ways.

The new user interface is recommended to address the requirements listed below.

Special character input: User interface should allow the use of special characters as input.

The user interface should provide a tool tip for the user input fields: Tool tip will provide more information about the input fields (see Figure 6.2).

Progress bar to indicate processing of document: While users wait for a document print to complete, a progress bar will keep users connected to the process (see Figure 6.2).

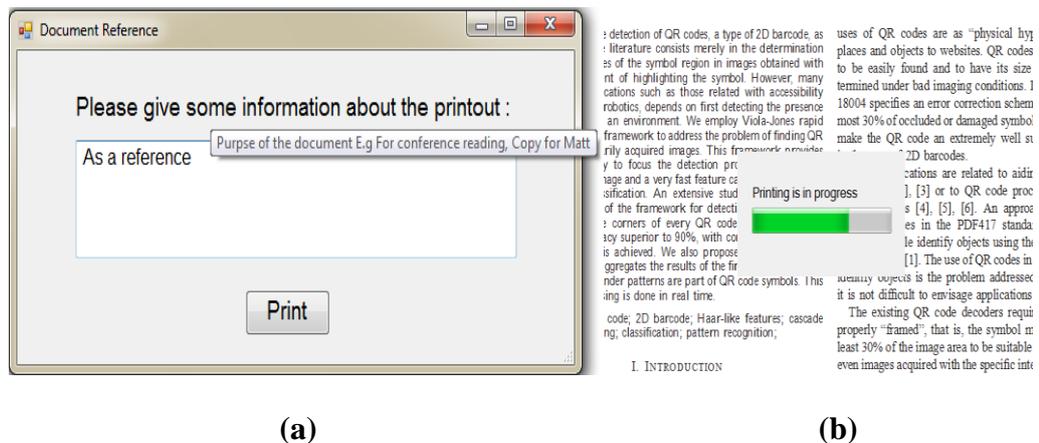
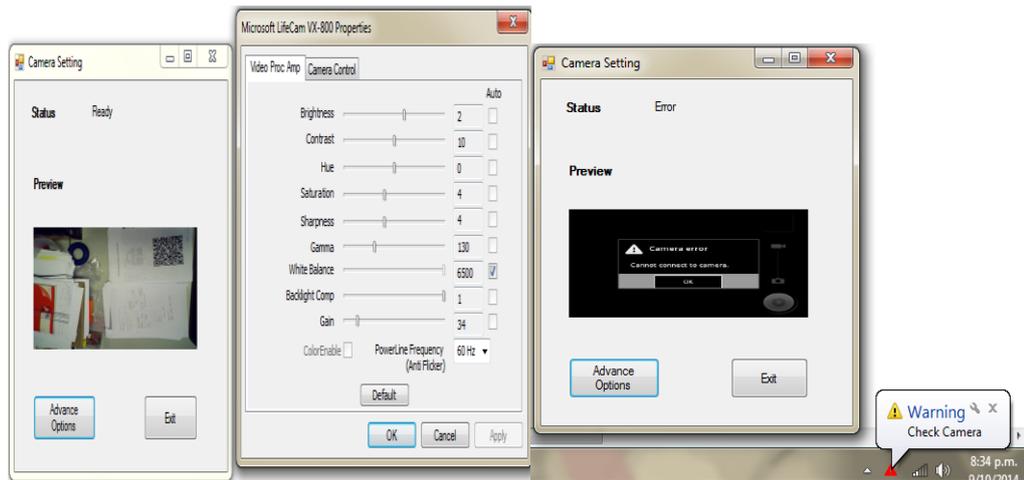


Figure 6.2 User Interface mock-up: (a) Tool tip mock-up (b) progress bar mock-up

User interface to check status of cameras in use: In the first prototype, the user was not given a camera information such as its current functioning status. The second prototype should include the camera status along with option of using advance setting to prevent the problem of camera failure. The interface will introduce a function warning the user if any camera becomes non-functioning (see Figure 6.3).



(a)

(b)

Figure 6.3 Camera setting mock-up: (a) Camera status with advance options (b) Camera error with warning notification

Mapping document on the floor map: Floor plan showing view from above illustrates the relationship between rooms, spaces and other physical feature. A floor plan not only a top view, it is also a measured drawing to scale of the room. Projecting or mapping document on a floor plan will give a user an accurate direction supported with distance and dimensions Figure 6.4 shows a mock-up image of a floor plan projecting the document highlighted in different colours, clicking on the document image will allow the user to gain more information about the document.

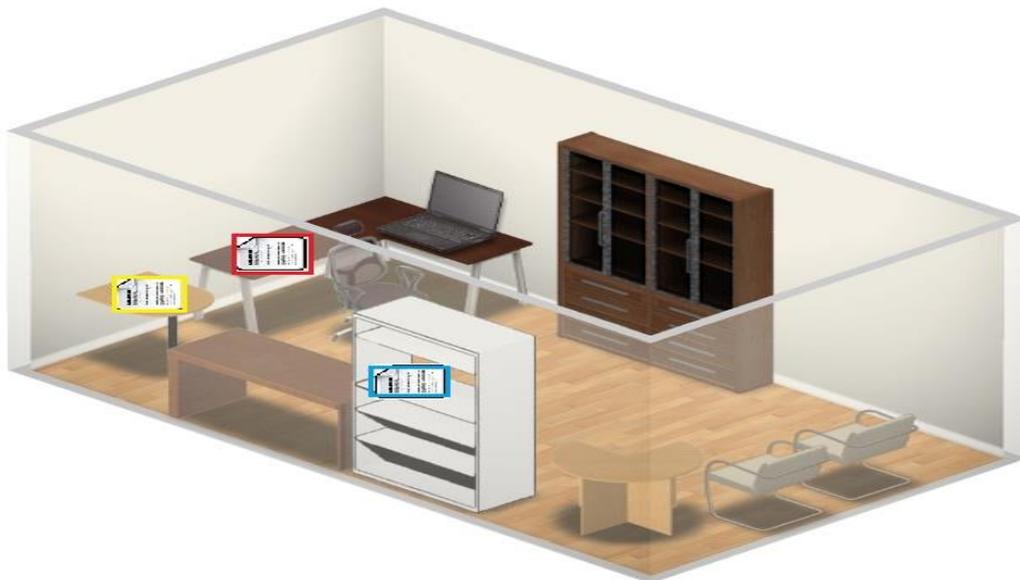


Figure 6.4 Document projection on floor plan, mock-up

6.3.3 Improved document identification (QR code decoding)

The tracking method used in current system can be optimized for even faster processing of the document images. Improving the speed of recognition of document and tracking the document tag would make the system more robust. Inconsistency in decoding of QR code will need to be addressed with use of more advanced QR code reader algorithms.

Another issue related to tracking the tag is its size; current tags are considered to be small in size for camera distance (over 125 cm). The possible solution is to use more high resolution cameras to cover the distance or increase the tag size up to 16-20 cm with use of smaller version of QR tags (QR version 1). It is observed that higher the QR tag version, the greater were size of tag to be read from distance. QR version 2 for distance over 125 cm requires QR code in print size of 19 – 57 cm. In relation to size and distance, we propose the improvement for the document identification (QR code reading) by increasing the size of print QR code tag on the document.

To have a good response from QR codes we will need to understand the use of hidden distance factor explained by Edward T Hall in his book ‘*The Hidden Dimension*’ (Hall, 1990).

Requirements for effective QR code read and decoding from distances

- Social distance QR code size (16-48 cm)
- Use of capital letters for QR code input
- Low level of error correction
- Use of smaller version QR code gives more radius
- Increase the size (dimension) of QR code for a read from distance

Another approach: Considering the difficulty and challenges in QR code identification, one may also consider using Image text localization on the whole front page of an article for document identification. Cameras might take images of the documents and text region detection and text extraction could be performed on those images, recognizing the particular text layout of each document. The extracted text region and text would be unique to every document and thus could be used for document identification.

6.3.4 Possible expansion with TRMS

A recent study on people strategies for keeping track of their digital documents shows the need for a system that records the material user is reading, been reading and plan to read (Alanazi, 2013).

As a result TRMS (Tracking Reading Material System) was developed; TRMS is a combination of two open source projects Greenstone and Zotero. TRMS uses Greenstone to share and organise documents and Zotero to capture the document and metadata. TRMS builds the library containing peoples reading, imported from Zotero and Greenstone (Alanazi, 2013).

HCW is constructed with goal of managing and keeping track of the physical documents; it further works in establishing linkage between physical document and its digital counterpart. Possible collaboration of TRMS and HCW will enable the user to take advantage of both systems from one platform. This gives advantage of not only keeping track of the document library but also expands it to tracking and managing those document even after printing in the real world.

6.3.5 Further evaluations

Our evaluation of the prototype was limited to only academic documents and to a limited number of users. Future evaluation should be conducted with a larger number of subjects and for extended period of time. Such experimentation will give us more accurate understanding of user's needs for managing and organizing their paper documents.

This study was limited by the study environment. In everyday use of HCW in different user environment might bring different findings in term of system design requirement and user behaviour.

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Appendix A – Material for the Usability Study

This appendix includes the material that was used in the user study.

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Rorohiko me ngā Pūtaiao Pāngarau
The University of Waikato
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24 June 2014

Amay Dighe
C/- Department of Computer Science
THE UNIVERSITY OF WAIKATO

Dear Amay

Request for approval to conduct a research evaluation involving human participants

I have considered your request to carry out a study for your Master's research project *Human Centered Workplace: Re-finding physical documents* using the prototype you have previously developed.

The purpose is to test the software with users to better understand the performance of the prototype.

Identification numbers will be used on the questionnaires to ensure confidentiality. We note that cameras will face the floor and the desk, no identifying images will be taken. The anonymized notes and video recordings will be kept for five years in the FCMS Archive, then destroyed.

The procedure described in your request is acceptable.

The research participants' information sheet, consent form and questionnaire meet the requirements of the University's human research ethics policies and procedures.

I therefore approve your application to perform the evaluation.

Yours sincerely,



Michael Mayo
Human Research Ethics Committee
School of Computing and Mathematical Sciences

Participant Information Sheet



Ethics Committee, Faculty of Computing and Mathematical Sciences

Project Title

Human Centered Workplace: Re-finding physical document.

Purpose

This research is conducted as partial requirement for Amay Dighe's Master thesis. This project requires the researcher to conduct the usability tests with the users to understand the performance of the prototype developed by the researcher.

What is this research project about?

'Human Centered Workplace' research aims to track and locate physical document in the workplace of the user. This current research is an extension to Amay Dighe's Post graduate Diploma dissertation study on the same topic, where Human Centered Workplace system conceptual design was developed. We built a prototype of the Human Centered Workplace software and wish to test it with users to better understand the performance of the prototype.

What will you have to do and how long will it take?

You will be asked to use the prototype to print and find documents. You will be given a scenario with some tasks to perform the prototype of the Human Centered Workplace. The study will take place in the computer science department's usability lab with the use of a desktop computer and two cameras installed in the environment to track the documents. The study will be video-recorded for identification of document location. No audio or videos are taken of participants (camera face the desk and floor area). It should not take longer than 30 min.

What will happen to the information collected?

The data collected will be used by the researcher as a part of Master's thesis report. It is possible that article and presentation may be the outcome of the research. Only the researcher will be privy to any notes, documents and recordings. The researcher will keep transcriptions of the recordings and a copy of the paper but will treat them with the strictest confidentiality. All notes will be anonymized as they are taken, video recording will be destroyed after the Master's thesis is written. The anonymized notes will be kept for 5 years in the FCMS archive. No participants will be named in the publication and every efforts will be made to disguise your identity.

Declaration to participants

If you take part in the study, you have the right to:

- Refuse to answer any particular question and to withdraw from the study before or after any analysis has commenced on the data.
- Ask any further questions about the study that occurs to you during your participation.
- Be given access to a summary of findings from the study when it is concluded.

Who's responsible?

If you have any questions or concerns about the project, either now or in the future, please feel free to contact either:

Researcher:
Amay Arun Dighe
G2.06, Department of Computer Science,
The University of Waikato
Phone: (07) 8384466 ext 6011
Email: aad11@students.waikato.ac.nz

Supervisors:
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G2.26, Department of Computer
Science, The University of Waikato
Phone: (07) 8384052
Email: hinze@cs.waikato.ac.nz

Research Consent Form



Ethics Committee, School of Computing and Mathematical Sciences

Human Centred Workplace: Re-finding physical document.

Consent Form for Participants

I have read the **Participant Information Sheet** for this study and have had the details of the study explained to me. My questions about the study have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I also understand that I am free to withdraw from the study before, or to decline to answer any particular questions in the study. I understand I can withdraw any information I have provided up until the researcher has commenced analysis on my data. I agree to provide information to the researchers under the conditions of confidentiality set out on the **Participant Information Sheet**.

- I agree / do not agree (please circle one) to participate in this study under the conditions set out in the **Participant Information Sheet**.

Signed: _____

Name: _____

Date: _____

- I want / don't (please circle one) want a copy of user study result

Signed: _____

Name: _____

Date: _____

Researcher's Name and contact information:

*Amay Arun Dighe
G2.06, Department of Computer Science,
The University of Waikato
Phone: (07) 8384466 ext 6011
Email: aad11@students.waikato.ac.nz*

Supervisor's Name and contact information:

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INTRODUCTORY QUESTIONS

1. How often do you search for documents that you have printed before?

— — —

Very Often Often Rare Very Rare

2. How much time you spend on document search?

— — — —

0-1 hour 1-2 hours 2-3 hours 3-4 hours 4-5 hours

3. How likely do you loose and re-print the document?

— — — —

Almost never Once in a while Sometimes Frequently Almost all the time

4. Any systems or techniques you use to keep track of printed material?

TASK 1: PRINTING FIRST COPY

Please select one of the document samples and print the document such that it can be tracked for its physical location.

- Successful printing

- Yes
- No

- How difficult was the printing such that the document can be tracked?



- Was the process time consuming

- Yes
- No
- Chance of improvement – please specify

- Is the information available about the document printout (first page) sufficient to identify the document?

- Yes
- No
- Chance of improvement – please specify

Other suggestion for task 1

TASK 2: PRINTING SECOND COPY

**Now place the document from task 1 somewhere in your workplace (in the usability lab).
Please print another copy of this document to give to someone else.**

- Successful printing
 Yes
 No

- How difficult was the printing of a second copy?



- Was the process time consuming
 Yes
 No
 Chance of improvement – please specify

- Is the information available about the document printout (first page) sufficient to identify the document?

- Yes
 No
 Chance of improvement – please specify

Other suggestion for task 2

TASK 3: FINDING A PHYSICAL DOCUMENT

Use the system to find the physical location of the first printed document.

- Successful finding

- Yes
- No

- How difficult was the finding of the physical copy?

Very Easy Easy Normal Difficult Very Difficult

- Was the process time consuming

- Yes
- No
- Chance of improvement – please specify

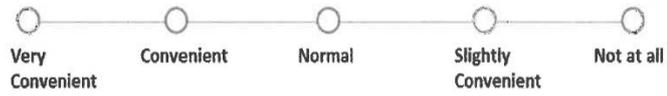
- Is the information available from the system sufficient to find the document?

- Yes
- No
- Chance of improvement – please specify

Other suggestion for task 3

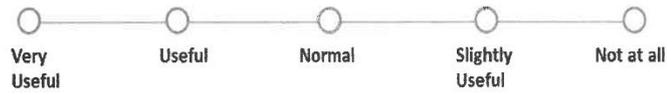
FEEDBACKS

5. How convenient was the software to use?



Reason:

6. How useful do you find this software ?



Reason:

7. Any suggestions about this prototype?

Thank you for your co-operation in completing this study.